The Effect of Students' Intrinsic Motivation on Situation Awareness with Attention as Mediator in a Virtual Reality Asphalt Compactor

Master Thesis

Educational Science and Technology

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Date:	22 november, 2023
Word count:	13099

Abstract

Situation awareness (SA) is essential when laying asphalt, for task performance and safety reasons. Therefore, it is important to identify which factors affect SA. Separate lines of research have shown an effect of motivation on attention and an effect of attention on SA. This study aimed to investigate if students' motivation also (indirectly) affects their SA, with attention as mediator. Forty-seven road construction students were recruited from vocational schools. Each of them took part in a virtual asphalt simulation with a VR head mount, which was screen-recorded. They also wore wristband trackers to record psychophysiological measurements. Participants' heart rate and skin conductance were measured and combined with the gaze-tracking of the screen recordings to indicate their attention. After the simulation, they filled in two questionnaires on their SA and their intrinsic motivation toward the asphalt training in VR. Results of the analysed data showed no effect of intrinsic motivation on attention, no effect of attention on SA, and no effect of intrinsic motivation on SA. Only a correlation was found between intrinsic motivation and attention. These results might be caused by the psychophysiological measures to indicate attention. Therefore, it would be useful to investigate other indicators of attention in the future, such as letting participants think out loud.

Keywords: situation awareness, intrinsic motivation, attention, Virtual Reality, vocational education, asphalt compacting simulation

Contents

The Effect of Students' Intrinsic Motivation on Their Situation Awareness

There is a shortage of road constructors in the Netherlands which is a problem since roads are a crucial part of our society. In 2018, the Netherlands had over 140 thousand kilometres of asphalt roads and almost 12.5 million registered road vehicles (CBS, n.d.; CBS, 2018). Without road constructors to build or repair roads, these vehicles cannot be used for transportation and therefore part of the mobile network would be down. A solution might be to stimulate more students to become road constructors because not many students choose this profession. However, stimulating students could be a complicated task since not all schools have space and money for an asphalt compactor on their school grounds. Therefore, students can only experience driving a compactor when they choose an asphalt laying internship. The University of Twente has started a possible solution: an asphalt compactor simulation in Virtual Reality (VR), with the goal of investigating students' awareness of the surroundings during asphalt compacting.

When compacting asphalt, being aware of the surroundings is essential for safety reasons (Endsley, 2000). Since operators are on big asphalt compactors, they must know if and where people or other obstacles are around them to make sure they do not hurt them or themselves. Moreover, being aware of the surroundings is also important for task performance. Operators must keep a close eye on multiple factors, for example on the weather given that asphalt is weather sensitive, and on the fuel gauge since their machines are driven by fuel. These are elements of situation awareness (SA), which can be defined as: 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future' (Endsley, 1988b, p. 792).

However, despite the importance of SA in the engineering work field and education, not all factors that are argued to affect SA have been researched. Endsley (2000) argued that, for instance, attention is a predictor for SA, where attention is used to only select relevant stimuli and ignore irrelevant stimuli (Chun & Wolfe, 2001). Multiple studies have confirmed this relationship between attention and SA (e.g., McCarley et al., 2002; Yang et al., 2020). However, it is still unknown how one's attention can be increased to also increase their SA, while this is important for education.

Previous studies have shown that someone's attention can be affected by their motivation (e.g., Robinson et al., 2012; Tomporowski & Tinsley, 1996). Motivation can be defined as being moved to do something in a specific context (Deci & Ryan, 2000). It is an important factor in education since students' motivation has an effect on school outcomes, such as learning effectiveness, learning outcomes, determination, and originality (e.g., Benbunan-Fich & Hiltz, 2003; Salzman et al., 1999; Wan et al., 2007).

As stated above, not all factors that are argued to affect SA are researched, despite SA being an essential skill in engineering. Studies have shown attention as a predictor for SA (e.g., Endsley & Smith, 1996; Gugerty, 1997). However, it is unknown how students' attention can be increased, to also increase their SA. Separate studies have shown an effect of one's intrinsic motivation on their attention (e.g., Robinson et al., 2012; Tomporowski & Tinsley, 1996). Regardless, it is undiscovered if there is an (indirect) effect of students' intrinsic motivation on their SA, with attention as a mediator.

For practice, it is important to identify factors that have an (indirect) effect on one's SA since SA contributes to task performance and, maybe more importantly, to safety in the workplace (Endsley, 2000). If factors that influence one's SA are found, we are a step closer to knowing how students' SA can be improved. Teachers can use this information while teaching, by playing into those factors. Therefore, this study aims to investigate the effect of the motivation of vocational education students on their SA during VR simulation and if attention mediates this effect.

Situation Awareness

The beginning of situation awareness (SA) as a concept is debated. Some say it is as old as the first philosophers since SA is in its core the relation between human's mind and their surroundings (Hoffman, 2015). Others trace it back to the First World War when a German air force fighter understood the importance of gaining awareness about the enemy (Endsley, 1988a). SA became more popular in the research field in the 1980s and the foundations for a theory on SA were created. In the 1990s, SA was defined as being aware of one's surroundings and comprehending the meaning of those surroundings for the present and the future (Endsley, 1995a). Nowadays, SA is an important, cognitive skill in engineering, and therefore also important in engineering education (Companion, 1989).

Endsley (1995a) developed a popular model, in which she theorized that one's SA contains three levels; perception, comprehension, and projection (see Figure 1 for a newer conceptual model of this theory). The lowest level of SA is called perception (Endsley, 1995a). For this level, one should be aware of key elements in their surroundings, and collect the key elements visually, auditorily, tactilely, or through smell, but without interpreting them (Endsley, 1988b; Endsley, 2021). For example, a road constructor sees a flashing on their dashboard, hears voices nearby, feels a sudden wind, or smells smoke. In all examples, the elements are only observed and not interpreted.

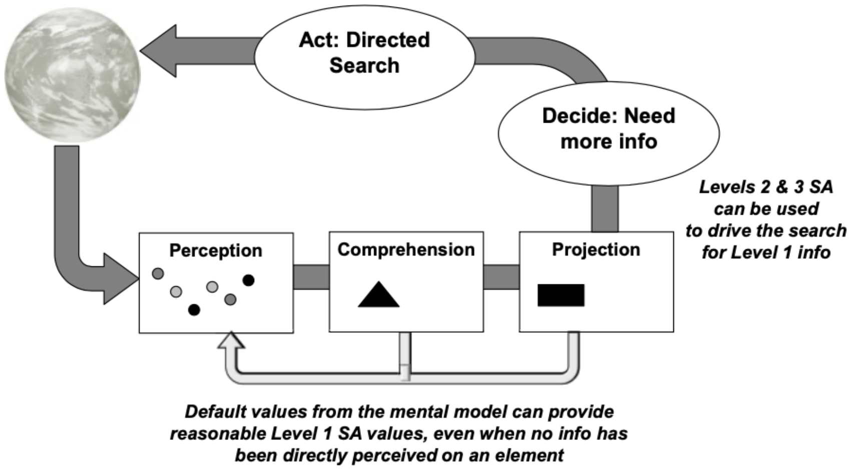
The second level of SA is comprehension and has level one as its foundation (Endsley, 1995a; Stanton et al., 2001). In this level, one can comprehend information about perceived key elements from level one and integrate those into their performance and associated goals. This process helps people understand what is happening around them (Jones & Endsley, 1996). For example, a road constructor sees a flashing on their dashboard and comprehends that their fuel tank is almost empty, they hear voices nearby and understand that there are people nearby, they feel a sudden wind and understand the weather is changing, or they smell smoke and understand that this is unusual.

Level three of SA is built upon both level one and level two and is called projection (Endsley, 1995a). It describes that one should be able to predict the state of their surroundings in the (near) future. This projection is based on information about key elements from level one of SA and on the comprehension and integration of these key elements into their performance and goals from level two. This level ensures that one can make a decision at the right time (Endsley, 1988b). However, when the information from level one and level two are incomplete, it is harder to foresee the future correctly (Stanton et al., 2001). For example, a road constructor sees a flashing light on their dashboard and comprehends that their fuel tank is almost empty. They project that their fuel tank will be empty in the near future and can make the decision to get extra fuel. Or a road constructor hears voices nearby and understands that there are people nearby. They project that this might cause dangerous situations in the future. Based on this projection, they can decide to pay extra attention to their surroundings. Alternatively, a road constructor feels a sudden wind and understands the weather is changing. Since this might have consequences for compacting, they can decide to change their plan for the day.

These three levels are hierarchical and thus managing the lower level(s) is needed to master the higher level(s) (Endsley, 1995a). However, this does not mean that the model is linear (Endsley, 2015). One can look for new key elements or interpret elements differently based on their current understanding and predictions and keep revising their SA (see Figure 1). For example, a road constructor smells smoke and understands that this is unusual. However, they cannot predict the future with this information alone. In situations like this, the constructor can go back to previous levels of SA. There might be more key elements around them (level one of SA) or interpret key elements otherwise (level two of SA).

Figure 1

Three Levels of Situation Awareness



Note. From "Situation Awareness Misconceptions and Misunderstandings" by M. R. Endsley, 2015, *Journal of Cognitive Engineering and Decision Making, 9*(1), p. 436 (https://doi.org/10.1177/1555343415572631). Copyright 2015 by the SAGE Publications.

SA is not a permanent state and depends on the surroundings. When one must effectively operate in complex environments, mastering the higher levels of SA is in particular essential (Endsley & Rodgers, 1998). When an operator is not sufficiently aware of the situation around them, the task performance reduces and the number of human errors increases (Salmon et al., 2009; Wickens, 2008). This can be dangerous during asphalt compacting, for example when people walk around the compacter and the driver is not aware of them. But when one is aware of the situation around them, task performance increases and the number of errors minimizes (Endsley, 1995b). However, achieving the required SA levels in complex environments can be hard. Since observing the stimuli in complex environments takes up a larger part of the working memory, less space is available to process, interpret and, project with these stimuli (Endsley, 1995b). This can cause significant information to get lost, by detecting it too late or not detecting it at all. It might be harder for people to achieve these higher levels of SA in complex situations. However, when people already experienced a similar situation before, they could have already organized their thoughts and behaviour into a mental model (McVee et al., 2005; Nguyen et al., 2019). Mental models are part of own's long-term memory, where previously gained information about the topic and the connections between the chunks of information are stored (Hoogendoorn et al., 2011). Experts already have a more extensive mental model and can integrate new elements more easily. They still have to revise their models but can add these new elements to their existing mental model (Hoogendoorn et al., 2011; Maes, 1990). In contrast, novices have a smaller mental model and might not be able to fit new elements into their limited reference points. Practicing different situations might therefore help with one's SA in complex situations. Because then people can rely on the patterns they have already constructed and build upon this prior knowledge (Neumann & Kopcha, 2018).

Attention

One's attention is argued to be a predictor of their SA (Endsley, 2000). Humans use attention to only select relevant stimuli and ignore irrelevant stimuli (Chun & Wolfe, 2001). This can be a both conscious and voluntary process (Schneider et al., 1984). But most of all, it is a necessary process, since the environment offers a lot of information at any given time. Without attention, our cognitive capacity would overload constantly (Chun & Wolfe, 2001). However, humans cannot constantly sustain an optimal state of attention. Their attention fluctuates over time (Esterman et al., 2014). It can be in an optimal state but can also be over-engaged for example when they overthink situations or under-engaged for example when they daydream. Moreover, when working on a task, attention can also decrease over time (Smallwood & Schooler, 2006; Warm et al., 2008). This can be caused by overload because of the size or difficulty of the task, or by repetition within a task.

A theory by Posner and Petersen (1990) divides attention into three primary constructs: alerting, orienting, and executive attention. These constructs are independent networks but also interact and influence the other networks. Alerting prepares one to become attentive to stimuli and stay in this alert form (Fan et al., 2009). However, staying alert does have a cost, since the error rates increase as well (Posner & Petersen, 1990). If the task that one has to pay attention to is longer, it is harder to keep paying attention (Thurstone, 1930). Orienting is defined as the network that directs one's attention to stimuli by disengaging, moving, or engaging (Posner & Petersen, 1990). Executive attention involves monitoring and resolving conflicts, which can occur between attentional cues (Fan et al., 2002).

Attention approaches

Over time, attention has primarily been approached as a domain-general construct. The Attention Network Task (ANT) by Fan et al. (2002) might be the most popular assessment to indicate one's attention in this manner. It consists of a computer task, where one has to press a specific key when the central arrow is pointed to the left and another specific key when it is pointed to the right (Petersen & Posner, 2012). Next to the central arrow, other arrows are introduced. These are either pointed to the same side as the central arrow or to the opposite side. The individual can derive where and when the next arrow occurs from information given before the task itself. Three scores are computed from this task, which relate to the performance in alerting, orienting, and executive attention (Fan et al., 2002).

If attention is approached as a domain-general construct, one's general level of attention and its components are measured over the whole task. Even though one can pay more attention during specific parts of the task and less attention during others (Esterman et al., 2014). Moreover, assessments like the ANT measure one's attention during their assessments, which are tasks on their own. To indicate attention during another task and at specific times during this task, a more situated approach should be taken, for which psychophysiological measurements can be used. These measures are indicators of bodily reactions that reflect changes in the psychological state and aim to measure the psychophysiological processes (Potter & Bolls, 2012; Richard & Haynes, 2002). Generally, the bodily reactions are shown in brief and small changes in specific psychophysiological measurements (Braithwaite et al., 2013). When combining these bodily changes with a change in context, a specific psychophysiological process can be indicated.

The psychophysiological measurement, heart rate is often used to indicate attention. The validation of this indication can be found in the biological connection between the human's automatic nervous system and their heart (Potter & Bolls, 2012). It is theorized that human's mental activities are driven by their psychophysiological processes, which indicates that human's mental processes can be studied by observing the activity of their automatic nervous system, including their heart. In practice, an increase in time between heartbeats or a decrease in the heart rate can indicate calming down to increase attention in reaction to an external stimulus (Wise, 2017). However, the change in time between heartbeats does not have to be brief (Bellman et al., 2019). If it stays lower for a longer period, it can also indicate lower attention.

An individual's skin conductance can indicate their attention as well. The validation of skin conductance as a measure of attention is also grounded in the automatic nervous system (Lempert & Phelps, 2014). Sweat on the skin occurs to regulate one's body temperature, but also as a reaction to one's fight-or-flight response (Edelberg, 1972). In practice, Bellman et al. (2019) made a distinction between a high attention level and a low attention level. A low attention level can be indicated by a brief decrease in skin conductance (Potter & Bolls, 2012). A brief increase in skin conductance implies an attention response to an external stimulus and thus a higher level of attention (Bellman et al., 2019).

Other and older studies came to the same conclusions: both skin conductance and heart rate can be used as indicators of attention (e.g., Frith & Allen, 1983; Richards & Casey, 1991; Turpin & Grandfield, 2009). Using these psychophysiological measurements instead of an assessment like the ANT makes it possible to measure one's attention during another task.

Visual Attention

A specific type of attention is visual attention, which focusses on visual stimuli. It is a form of attention that improves human's performance in visual tasks, as well as dealing with human's limited capacity to process visual information (Carrasco, 2011). Classically, visual attention was seen as a spotlight casting over the surroundings, also called overt attention (Posner, 1980). It can be discovered by one's eye movement toward a position. For example, a road constructor focusses their visual attention on their colleague walking by. Overt attention can be measured with eye-tracking and indicated with psychophysiological measurements (Carrasco, 2011; Posner, 1980). However, visual attention does not only take place by focussing their eyes on one relevant location, but also by monitoring the space around that one location (Carrasco, 2011; Kanwisher & Wojciulik, 2000). This is called covert attention, which can be deployed to more than one location at a time, since actually looking at the location is not required (Carrasco, 2011; Posner, 1980). For example, a road constructor focusses their visual attention on the road and sees a flashing light at the bottom of their range of vision. Covert attention can be indicated with psychophysiological measurements. One's covert attention tracks the environment and guides their overt attention to relevant information in the environment (Carrasco, 2011).

Situation Awareness and Attention

As mentioned above, Endsley (2000) has argued that attention is a predictor of SA. In general, SA and attention are correlated. Research showed that people with a higher SA checked places where hazards could occur periodically and generally scanned their surroundings more often, unlike people with a lower SA (Hasanzadeh et al., 2018). The attention/situation awareness model adds that one's workload has a negative effect on their attention, and thus on their SA since the information collected by their attention gets passed to their SA module (McCarley et al., 2002). In the SA module, the information is comprehended and integrated into their performance and associated goals (level two of SA). Information from this process is sent back to the attention module, where it is used to guide their attention (McCarley et al., 2002).

Because of the limited amount of space in human's working memory, people focus their attention on more relevant or urgent stimuli when their work increases (Gugerty, 1997;

Endsley & Rodgers, 1998; Endsley & Smith, 1996). They use their limited capacity to pay attention to the key elements in their surroundings. For example, fighter pilots could recall targets that were instantly threatening better and named these targets first (Endsley & Smith, 1996). The errors fighter pilots made were often related to less threatening targets. Car drivers and air traffic controllers behaved in the same manner. Car drivers paid closer attention to the most important cars when there were too many cars to keep track of (Gugerty, 1997). These vehicles were hazardous, or front and nearby. Air traffic controllers' attention decreased for less relevant information when their work increased (Endsley & Rodgers, 1998). Hence, they could keep their attention on more important information. This process of focussing their attention on more important stimuli does however affect their SA since they are less or not aware of other elements around them (Endsley & Smith, 1996).

However, everyone has to consider and decide for themselves which elements are important (Yang et al., 2020). Influential elements can be an important stimulus for an individual, while this is not advantageous for one's SA. An example of a distracting and not advantageous stimulus is a mobile phone while driving in traffic (Yang et al., 2020). If people used their phone while driving, it lowered their SA. The phone took up their overt visual attention, therefore people could only monitor the traffic around them with their covert attention. Thus, instead of using the limited capacity of their attention for paying attention to hazardous cars, people can choose other distracting stimuli as more relevant or urgent stimuli.

Thus, previous studies show that people with higher levels of SA look around more often than people with lower SA. Also, workload has a negative effect on attention and thus on SA. Therefore, when people encounter complex situations with more stimuli, they focus their attention on the most relevant stimuli. The relevance of these stimuli is judged by the individual themselves. However, these studies have only researched the relation between SA and attention when attention was approached as a domain-general construct. Attention and its components were only measured in general levels and during the task of the assessment. The relationship between SA and attention has not been researched when the focus of attention was measured during the whole task and during another task not related to an attention assessment. Moreover, students have not been the respondents and a VR asphalt compactor simulation has not been the experimental setting in previous studies.

Another aspect that is not yet researched in the SA domain, is the relation between SA and motivation, with attention as a potential mediator. Yang et al. (2020) showed that influential elements like their mobile phones can take up drivers' attention and therefore lower their SA. An aspect that might be of influence in this situation is motivation since motivation powers people to act or behave the way they do (Deci & Ryan, 2000).

Motivation

To succeed in school, researchers have argued that having a certain level of knowledge or skill is not enough (Paris et al., 2001). Students also need to be positively motivated to do well. Motivation is the force behind the way people act and behave (Reeve et al., 2007). This motivation can be intrinsic and extrinsic (Deci & Ryan, 2000). One is intrinsically motivated when they participate in an activity for its own sake, because of their own choices, interests, and values. This form of motivation is driven by internal factors. For example, students drive an asphalt compactor because they enjoy it or find it interesting. In contrast, one is extrinsically motivated when they participate because of external factors, such as receiving an award or avoiding a punishment (Deci & Ryan, 2000). This form of motivation is driven by what is gained by doing the task and does not lead to long-term change. For instance, students drive an asphalt compactor to be able to finish their studies. Thus, the concepts of intrinsic and extrinsic motivation can be divided by one's reasoning behind doing a task (Deci & Ryan, 2000). This does not mean that intrinsic motivation and extrinsic motivation are two independent constructs. One's motivation does not have to be only intrinsic or extrinsic (Covington & Mueller, 2001). Their reasoning can be based on both intrinsic and extrinsic factors. For example, students can like driving an asphalt compactor and also drive it to finish their studies.

These concepts of intrinsic and extrinsic motivation are part of the Self-Determination Theory (SDT) by Deci and Ryan (1985). For the current study, the SDT will serve as a base for the concept motivation. The SDT states that humans are naturally motivated to develop themselves (Deci & Ryan, 2000; Ryan & Deci, 2000). However, for them to be motivated intrinsically, they have three basic psychological needs: to feel competence, to feel autonomous, and to have a sense of relatedness (Pintrich, 2003; Ryan & Deci, 2000). The need for competence refers to the want to master one's activity, the need for autonomy involves the want to be given freedom of doing activities on one's own and to be able to accomplish activities on one's own, and the need for relatedness refers to the want to connect with others. An environment that fulfils all three needs, promotes humans to be intrinsically motivated (Reeve & Jang, 2006; Ryan & Deci, 2000).

Attention and Motivation

Previous studies have shown a positive effect of motivation on attention. More specifically, one's extrinsic motivation can affect one's attention. Research showed that participants who were promised an extrinsic reward had a significantly higher average in fixation duration than participants without promised rewards (Pieters & Warlop, 1999). It was concluded that participants' extrinsic motivation affected their visual attention. Not only rewards but also punishments can affect one's attention. Engelmann and Pessoa (2014) showed that one's orienting of attention can be increased by using rewards and punishments. Hence, participants detected more changes when they could win rewards or avoid punishment than when rewards and punishments were absent.

People's intrinsic motivation also correlates with their attention. For example, participants who described their motivation with the term boredom were less likely to pass the attention check (Jun et al., 2017). The attention check was placed inconspicuously in the questionnaire and asked participants to perform a task to determine if participants paid attention to the questionnaire. The performance in the attention check of participants from the boredom group was significantly lower than that of participants who described their motivation with the terms: compassion, fun, science, or self-learning. Robinson et al. (2012) also studied the relationship between intrinsic motivation and attention but divided attention into the constructs: alerting, orienting, and executive control (derived for the ANT by Fan et al. (2002)). The results showed a significant correlation between participants' motivation and their attentional alertness (Robinson et al., 2012). Moreover, participants also performed better in the executive control network task when they had a higher motivation. No correlation was found between participants' motivation and their orienting attention.

Thus, previous research shows that external stimuli have an effect on one's attention, when a reward is promising after a monotonous task, and when rewards and punishments are given during a task. People can orient their attention longer and reorient their attention better on stimuli, and they can settle conflicts between stimuli better when they are extrinsically motivated. In relation to intrinsic motivation, there is at least a correlation between intrinsic motivation and attention. More specifically, there is a correlation between intrinsic motivation and the alerting network, and between intrinsic motivation and the executive control network. However, these studies have not researched the relationship between one's intrinsic motivation and their attention, only a correlation has been confirmed. Furthermore, when researching this correlation, attention was approached as a domain-general construct. A general level of attention and its components were measured during an assessment-specific task. Attention has not been approached as a situated construct yet, which can be done by indicating one's attention with psychophysiological measurements. This enables researching the correlation between one's motivation towards a task and their attention during this task can be researched.

Thus, Jun et al. (2017) and Robinson et al. (2012) have shown a correlation between intrinsic motivation and attention. Moreover, researchers such as Hasanzadeh et al. (2018), Endsley and Rodgers (1998), and Yang et al. (2020) demonstrated the relationship between attention and situation awareness. However, as stated before, there is no research on the effect of intrinsic motivation on SA with attention as a mediator.

Research Questions and Hypotheses

This study aims to investigate the relationship between the motivation of vocational education students and their SA during an asphalt training VR simulation. As written in the previous paragraphs, research has shown the effect of intrinsic motivation on attention, which in turn is argued to be a predictor for SA. This might suggest an (indirect) effect of students' motivation on their SA. However, this effect has not been explored yet in research. Therefore, the first research question of this study and its corresponding hypothesis is as follows:

- *Research question 1:* Does the intrinsic motivation of vocational education students toward a virtual asphalt training affect their situation awareness during an asphalt training VR simulation?
- *Hypothesis 1:* Students' intrinsic motivation toward the virtual asphalt training has a positive effect on their situation awareness during the asphalt training VR simulation.

To investigate whether attention mediates this possible effect, a second research question is formulated, with corresponding hypotheses (see Figure 2 for a visual display):

- *Research question 2:* Does the attention of vocational education students mediate for the effect of their intrinsic motivation toward a virtual asphalt training on their situation awareness during an asphalt training VR simulation?
- *Hypothesis 2a:* Students' intrinsic motivation toward the virtual asphalt training has a positive effect on their attention during the asphalt training VR simulation.
- *Hypothesis 2b:* Students' attention has a positive effect on situation awareness during the asphalt training VR simulation.
- *Hypothesis 2c:* Students' attention mediates the effect of their intrinsic motivation toward the virtual asphalt training on their situation awareness during the asphalt training VR simulation.

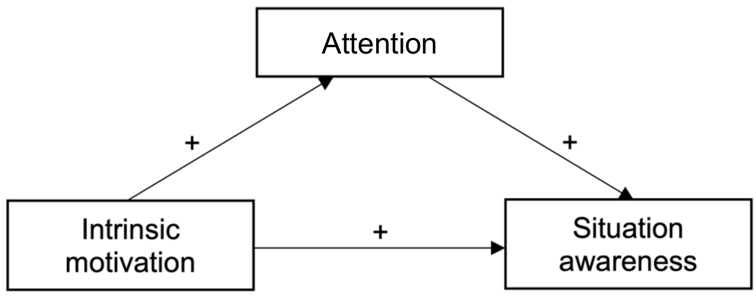
To explore if a portion of attention can be attributed to visual attention, a third research question was formed:

- *Research question 3:* Can the visual attention of vocational education students be identified from their attention during an asphalt training VR simulation?

Moreover, the duration of the asphalt training VR simulation was included as an explorative variable in this study. This way, it could be investigated if students who spend different amounts of time in the simulation also show a difference in their attention.

Figure 2

Conceptual Model of Hypotheses



Research Design and Methods

Research Design

For this study, both quantitative and qualitative research designs were used. The asphalt compactor simulation was part of an experimental design (Creswell, 2012). Participants could get a simulation with a duration of four or eight minutes. The difference in duration was generated to investigate a possible correlation between duration and one of the other variables. The assigning of participants to the four-minute group or eight-minute group was not random but based on the amount of time available at each school. Moreover, a cross-sectional survey design was used to investigate participants' SA during the simulation and their motivation towards the simulation (Creswell, 2012). Lastly, for the observational design, the simulation was screen-recorded to match participants' higher attention based on their heart rate and skin conductance with a visual stimulus in the simulation around the same time (Creswell, 2012).

The data collection process of this research project is in line with the ethical guidelines of the University of Twente and before the start of this process, permission for this research was given by the Ethics Committee of Behavioural, Management, and Social Sciences (BMS; request number 211123).

Respondents

To gather respondents, vocational schools in The Netherlands were asked to participate by email. All schools had to have an educational program that included road construction technology. In practice, that meant only schools with a program to become civil engineers or road construction operators were approached (in Dutch these programs are called *Machinist Grondverzet* or *Machinist GGW*). In the end, three vocational schools participated, with one class each and all with a Machinist Grondverzet program (n = 21.3%, 29.8%, and 48.9%). The 48 participants were recruited by a technique called convenience sampling since only participants who were available by chance could take place in this research (Creswell, 2012). Data from only 47 participants are included in this study since the dataset was not complete for one of the participants. All 47 participants were male and were between 16 and 23 years old (M = 18.39; SD = 1.83). Most of them were in their first year of the program (91.50%).

Procedure

Before the experiments started, the researcher explained the study globally to all participants in the classroom and handed out active consent forms, in which the study was further explained. The students were told that they must sign the form to participate. No participants dropped out because of this criterion. If there were no questions, the first student(s) came to the testing room (one per testing station). Each participant took place at a testing station, which contained a laptop with a VR head mount, steering wheel, and joystick. They handed over their signed consent form and got a short, more specific explanation about what was going to happen during the study. Then each participant put on two of the Empatica Wristband Trackers under the guidance of the researcher, each on one arm. Next, the researcher noted if the participant was right- or left-handed.

After preparations, the VR asphalt training application was started by the researcher. This training was specifically designed for an ongoing study, in which researchers explore the learning performance of participants practicing their road construction skills in VR. For this study, the head mount was connected to a laptop. During the experience, participants were instructed to compact a T-junction with an asphalt compactor. They could move their head to look around in the 360° environment, steer with a steering wheel, and throttle and brake with a joystick. Each participant went through the VR asphalt training application as follows:

- The participant typed in their name and were given an ID number.
- Some basic information about the experiment was given through an audio fragment.
- Their assignment was explained in a virtual working meeting (see Figure 3). They could click on eight questions to receive pieces of information about their assignment.
- To make sure all participants understood their task, four multiple-choice questions were asked about the explanation. For example: Which compactor are you driving today?, with the answer options: first, second or third. Right after they selected an option, the laptop showed the right answer by making it green. All questions can be found in Appendix C.
- When finished, the laptop showed how participants could use the steering wheel and joystick to drive the compactor.
- The simulation itself started and participants could put on the VR head mounts under the guidance of the student-researcher. They went through the whole virtual asphalt training until four or eight minutes had passed (depending on their experiment condition) and the application stated the simulation had ended (see Figure 4).
- Lastly, they filled out the SA questionnaire on the laptop and the motivation-questionnaire toward the virtual asphalt training on paper. On the same paper, six other questions were asked about participants' background information, in particular their gender, age, school, year, experience with a compactor, and experience with VR.

Both the intrinsic motivation questionnaire and the consent letter contained an id-number, so forms could be matched.

The whole experiment took approximately fifteen to twenty minutes per participant and took place during school time at the schools of the participants. Furthermore, the experiment was standardized, and thus the events during the experiment and the set-up of the experiment were the same for each participant.

Instrumentation

Various instruments were used to assemble data. Participants had to work with all instruments to participate in the study.

Situation Awareness

Participants' SA was measured with a questionnaire, developed for ongoing research. It is based on the Situation Awareness Global Assessment Technique (SAGAT) by Endsley (1988b). The questionnaire consisted of twelve questions, four on each level of SA: perception, comprehension, and projection. All questions were closed-ended and could be answered by selecting one of the three or four multiple-choice options. Participants could read and answer these questions on the laptop immediately after the simulation. All questions had only one correct answer, except for question 1 (*Where is the first asphalt compactor now?*) where the right answer lay between option 1 and option 2. Both options were considered correct. The overall score was calculated by counting the number of correct answers for each participant (see Appendix B for the questions with associated multiple-choice options and correct answers).

When calculating a reliability analysis, the SA questionnaire had a Cronbach's alpha of .37, which Field (2018) labels as a low reliability. One item that was answered notably bad, was item 3 (*How many times have you compacted the marked section?*). The percentage of students who answered this multiple-choice question right was significantly lower than answering it by chance (see Table 1). Moreover, item 7 (*What phase of asphalt compacting are you in?*), item 8 (*What do you need to pay most attention to?*), item 9 (*Will the first asphalt compactor transfer to another area?*), and item 10 (*Do you need to adjust your strategy in the future?*) did were not answered significantly higher or lower than answering them by chance (see Table 1). These five questions do not appear to have a similar theme and they aim to measure all three levels of SA. From a methodological perspective, it was decided to delete all five items from the questionnaire and exclude them from the results of this study.

Figure 3

Virtual Work Meeting

Figure 4

Participant during VR Asphalt Training

Attention

Participants’ attention was measured using the Empatica E4 Wrist Trackers. Empatica E4 Wrist Trackers are designed to track various psychophysiological measurements, namely participants’ temperature, skin conductance, possible changes in blood volume, acceleration, time between individual heartbeats, and heart rate (Empatica, n.d.). Empatica advises users to wear one wristband tracker, only on the dominant arm. However, exploration of the equipment exposed that the wristband could lose contact with the wrist when someone moves their arm. Since participants had to steer a steering wheel and thus move their arms during the simulation, two wristband trackers were used per participant instead of one. Nevertheless, the researcher did use the data from their dominant hand as the main data.

For this study, participants’ skin conductance and heart rate were used to measure their attention. For both parameters, the mean and standard deviation of each participant were calculated over the time of the audio fragment participants had to listen to (see paragraph 2.3, point 2). Figure 5 and Figure 6 show the skin conductance and heart rate of one participant over the whole experiment. The blue horizontal line represents their mean, and the two grey lines represent the standard deviation above and below the mean. The two black vertical lines illustrate the start and end of the asphalt compactor simulation. The number of seconds the graph came above the mean and one standard deviation during the simulation were calculated for both variables (see Appendix D and Appendix E for Python code). The value of one standard deviation above the mean was chosen since the standard deviation describes the spread of the data points (Field, 2018). Therefore, when data points are above the mean and one standard deviation, those data points are considerably higher than the average value. Thus, when the graph comes above this value, a participant’s skin conductance or heart rate is considerably higher than their average skin conductance or heart rate, which can indicate an increase in their attention (Frith & Allen, 1983; Richards & Casey, 1991).

Table 1

Answers from the Situation Awareness Questionnaire

	Item	# correct answers	% correct answers	# answer options	Correct by chance	< or > than chance [a]
1	Where is the first asphalt compactor now?	37	78.72%	4	50%	Higher**
2	Where is the asphalt paver now?	39	82.98%	4	25%	Higher**
3	How many times have you compacted the marked section?	5	10.64%	3	33.3%	Lower**
4	Which setting are your sprinklers in now?	30	63.83%	4	25%	Higher**
5	What effect does the weather have on your work?	31	65.96%	3	33.3%	Higher**
6	With how much width do you have to track now?	25	53.19%	3	33.3%	Higher*
7	What phase of asphalt compacting are you in?	11	23.40%	3	33.3%	Lower
8	What do you need to pay most attention to?	14	29.79%	3	33.3%	Lower
9	Will the first asphalt compactor transfer to another area?	17	36.17%	4	25%	Higher
10	Do you need to adjust your strategy in the future?	17	36.17%	4	25%	Higher

	Item	# correct answers	% correct answers	# answer options	Correct by chance	< or > than chance [a]
11	How long will it take for your fuel tank to be empty?	32	68.09%	3	33.3%	Higher**
12	Do you foresee problems with your task?	35	74.47%	4	25%	Higher**

Note. $N = 47$

[a] One sample t-test, with a 95% confidence interval.

$^{*}p < .005$ (1-tailed). $^{**}p < .001$ (1-tailed).

Figure 5

Heart Rate Data from a Participant

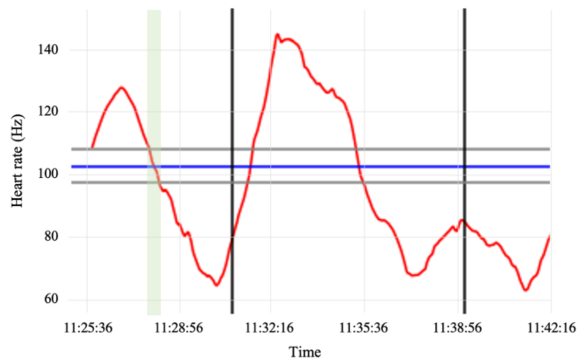
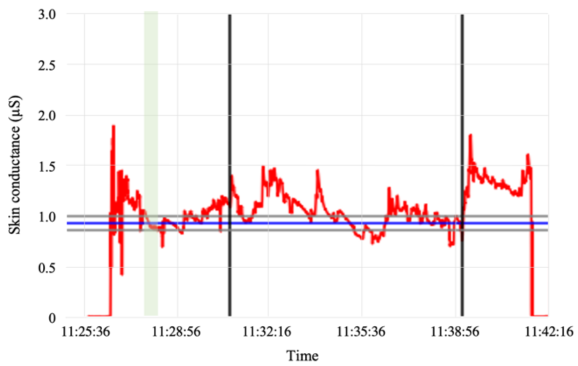


Figure 6

Skin Conductance from a Participant



Visual Attention

Data from the Empatica E4 Wrist Trackers were combined with the screen recording of each simulation to analyse what stimuli participants' attention was focused on. Hence, Villa et al. (2020) state that visual attention can be assessed by combining skin conductance, heart rate, and eye tracking. For this study, the screen recording of each simulation was used to track a participant's gaze. The specific times when peaks of participants' skin conductance or heart rate came above the calculated baseline were matched with the same timestamps in the screen recordings. When a change in the simulation happened during these times, it was noted. The changes were mainly caused by the participants themselves. For example, participants could start the asphalt paver, look in a mirror, or drive from the asphalt. Only a few changes were generated by the simulation itself, and thus without the influence of a participant. Those were the behaviour of the asphalt paver (starting, driving, and stopping) and the ending of the simulation. By combining the peaks in participants' skin conductance or heart rate with the screen recordings, participants' higher attention could possibly be matched with visual stimuli during the simulation.

An inductive approach was used to analyse the screen recordings, which entails that themes were drawn from the raw data (in this case the screen recordings; Thomas, 2006). All screen recordings were watched, and fifteen seconds before and after each peak in one's skin conductance and heart rate were closely observed. When participants showed different behaviour at the time of or just after a peak, this behaviour was noted. After watching all videos, the changes in behaviour were compared, themes were derived from these changes, and the changes were categorized into the themes.

Intrinsic Motivation

Participants' intrinsic motivation toward the virtual asphalt simulation was measured by an existing questionnaire. It is a variation of the Intrinsic Motivation Inventory, developed to measure participants' intrinsic motivation towards a certain task instead of an activity in a laboratory (Centre of Self-Determination Theory, n.d.). This questionnaire was originally in English but was translated by Kamstra (2015) to Dutch. The Dutch questionnaire had a Cronbach's alpha of .60 (Kamstra, 2015). For this research, the specific task was replaced by the asphalt compactor simulation. The questionnaire contains 22 items. Each item has a 7-point Likert scale, where 1 stands for *completely untrue*, 4 for *neutral*, and 7 for *completely true*. The questionnaire is designed to measure four subscales: interest/enjoyment, perceived competence, perceived choice, and pressure/tension. Where interest/enjoyment is a self-report measure of intrinsic motivation, perceived competence, and perceived choice are positive predictors, and pressure/tension is a negative predictor (Centre of Self-Determination Theory, n.d.). Kamstra (2015) also calculated the reliability of each subscale: interest/enjoyment has a Cronbach's alpha of .90, perceived competence .77, perceived choice .69, and pressure/tension .51 (see Appendix A for the whole questionnaire of this study).

When calculating a reliability analysis, it showed that the questionnaire had an overall Cronbach's alpha of .76, which Field (2018) labels as reliable. The constructs interest/enjoyment and perceived competence within the questionnaire were both reliable as well (see Table 2). However, the Cronbach's alpha of the construct perceived choice was just under the acceptable standard for reliability (Cronbach's α = .59, which is lower than .60). Lastly, the construct pressure/tension had a low reliability, Cronbach's α = .49. Deleting items from any of the constructs would not increase the Cronbach's alphas much, therefore none of the items were deleted from the questionnaire.

Table 2

Constructs from the Intrinsic Motivation Questionnaire

Construct	# items	Items numbers	Reliability (Cronbach's alpha)
Interest/enjoyment	7	1, 5, 7, 9, 14*, 16, 20	.87
Perceived competence	5	4, 11, 12, 15, 22	.76
Perceived choice	5	3, 10*, 18, 19*, 21*	.59
Pressure/tension	5	2*, 6, 8*, 13, 17	.49

Note. * Item is mirrored.

Data Analysis

All data from this study was collected over one week, using multiple instruments. The data contain one dependent variable (participants' SA), one independent variable (participants' intrinsic motivation), and one possible mediator variable (participants' attention; see Figure 2).

To answer the research questions of this study, first, the data had to be prepared. The data from the Empatica Wristband Trackers were divided per participant and per psychophysiological measurement with a Python program (see Appendix D and Appendix E for Python code). Next, all quantitative data from the Intrinsic Motivation Questionnaire, the SA questionnaire, and the number of seconds and the average height above the baseline were manually inserted into Statistical Package for the Social Sciences (SPSS). Descriptive analyses were calculated for all added data. To calculate the overall intrinsic motivation, items from the construct pressure/tension were mirrored, since it is a negative indicator of intrinsic motivation. A lower score on this construct indicates higher intrinsic motivation. The mirrored pressure/tension items were also used to compare them with the other constructs. An independent t-test was calculated to determine if there was a difference in attention based on the length of the simulation. Next, participants' psychophysiological measures were corrected because of the difference in simulation duration. Participants' heart rate and skin conductance were divided by two when they worked with the eight-minute simulation. Spearman's rho was used to calculate possible correlations between participants' motivation, the four constructs of motivation, their skin conductance, their heart rate, their overall SA score, and their score on the individual items of SA. Spearman's rho was chosen over Pearson's r, since motivation and its constructs have an ordinal scale, the individual items of SA have a nominal scale, and participants' skin conductance and heart rate are not normally distributed. For Pearson's r, both variables must have an interval or ratio scale and must be normally distributed (Field, 2018).

To answer research question 1 and test its corresponding hypothesis, a bivariate linear regression analysis was computed. The hypotheses of research question 2 were tested by calculating multiple linear regression analyses, where the possible mediation was analysed with the PROCESS macro, model 4 by Hayes (2017). With these results, the research question itself was answered. For all analyses, models were made with combinations of the variable measures. Lastly, for research question 3, the time of peaks in participants' heart rate and skin conductance was compared with activities in the screen recordings during those times.

Results

Descriptive Statistics

Descriptive statistics were calculated for the remaining seven questions of the situation awareness questionnaire. On average, participants answered 6.08 of these questions correctly with a standard deviation of 1.56 (min. = 3 and max. = 7). The number and percentage of participants who answered a certain question correctly was also computed (see Table 1).

The Empatica Wristband Trackers were used to determine participants' heart rate and skin conductance. Values from the eight-minute simulations were divided by two to be able to compare the values from the four- and eight-minute simulations. On average participants' skin conductance during the four-minute simulation came 202.09 seconds above the baseline, with a standard deviation of 110.32 seconds, a minimum of 0.00 seconds, and a maximum of 350.00 seconds (see Figure 7). Participants' skin conductance during the eight-minute simulation came on average 182.31 seconds above this baseline. It had a standard deviation of 99.22 seconds, a minimum of 0.00 seconds, and a maximum of 273.00 seconds. The number of seconds participants' heart rate came above the baseline was much lower than participants' skin conductance during both the four-minute simulations and the eight-minute simulations. On average 10.07 seconds with a standard deviation of 21.47 seconds, a minimum of 0.00 seconds, and a maximum of 71.75 seconds during the four-minute simulations (see Figure 8). Participants' heart rate during the eight-minute simulations had a mean of 7.70 seconds, a standard deviation of 13.01 seconds, a minimum of 0.00 seconds, and a maximum of 51.75 seconds.

In addition, the data of the Empatica Wristband Trackers were used to calculate the average spread above baseline for both participants' skin conductance and heart rate during the four- and eight-minute simulations. Participants' skin conductance came 0.70 µS above the baseline on average during the four-minute simulations, with a standard deviation of 0.37 µS (see Figure 9). During the eight-minute simulation, participants' skin conductance came on average 0.71 µS, with a standard deviation of 0.38 µS. In both the four- and eight-minute simulations, participants' skin conductance had a minimum of 0.00 µS, and a maximum of 1.00 µS. Participants' heart rate was spread 0.15 Hz above the baseline. It had a standard deviation of 0.31 Hz, a minimum of 0.00 Hz, and a maximum of 1.00 Hz. On average participants' heart rate was 0.12 Hz above the baseline, with a standard deviation of 0.21 Hz, a minimum of 0.00 Hz, and a maximum of 0.83 Hz.

When comparing the means of participants' heart rate during four-minute simulations and eight-minute simulations, no significant differences were found (see Table 3). Moreover, no significant differences were found between the means of participants' skin conductance, when comparing them during both durations of the simulation. The difference in duration will therefore not be included in the remaining results.

Descriptive statistics of the Intrinsic Motivation Inventory were calculated as well (see Table 4). Overall, the participants had an average intrinsic motivation score of 5.54 with a standard deviation of 0.66. The average score is higher than the midpoint of the 7-point Likert scale. However, the means of item 4 (I think I am pretty good at this task compactor simulation), item 12 (I think I did pretty well at the compactor simulation, compared to other students), and item 15 (I felt pretty skilled at the compactor simulation) score below the midpoint. These items are all part of the construct perceived competence. The other two items of this construct show below the overall average as well. Also noticeable is that half of the items have a minimum score of 1 and a maximum score of 7, which shows the contrasting motivations among the participants.

Figure 7

Number of Seconds Participants' Skin Conductance Came above the Baseline

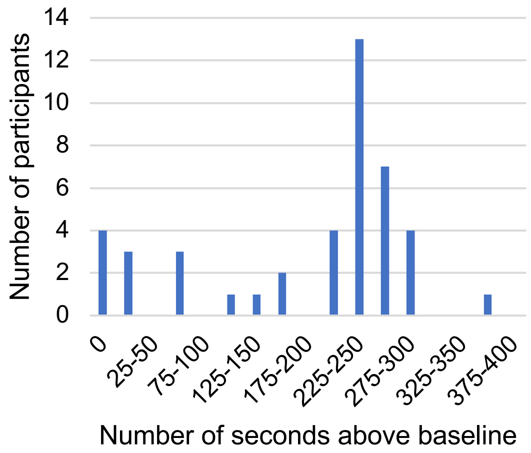


Figure 8

Number of Seconds Participants' Heart Rate Came above the Baseline

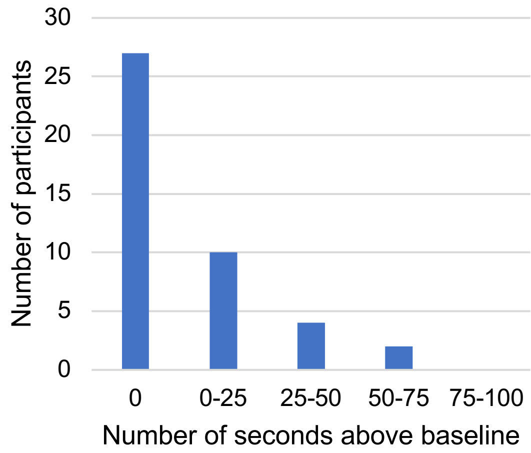


Figure 9

Average Spread of Participants' Skin Conductance Came above the Baseline

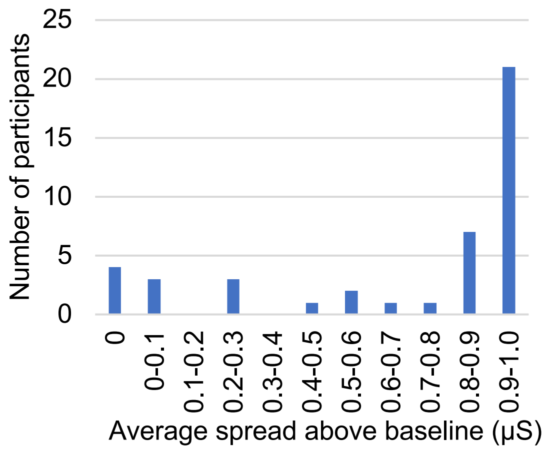


Figure 10

Average Spread of Participants' Heart Rate Came above the Baseline

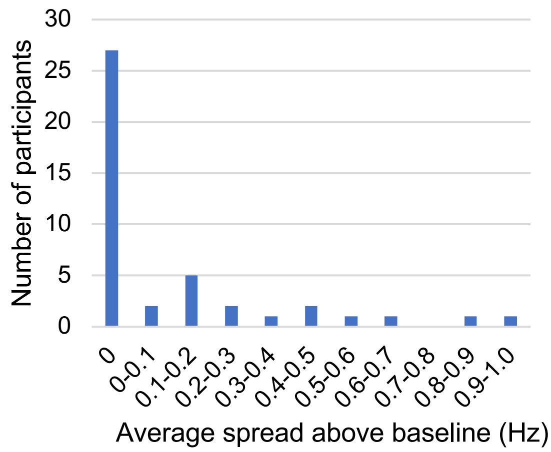


Table 3

Independent T-Test of Attention Variables during Four- and Eight-Minute Simulations

Attention variables	4 minutes		8 minutes		*t*(47)	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Heart rate, seconds above baseline	10.07	21.47	7.70	13.01	0.655	0.327	0.15
Skin conductance, seconds above baseline	202.09	110.32	182.31	99.22	0.558	0.279	0.19
Heart rate, spread above baseline	0.15	0.31	0.12	0.21	0.776	0.388	0.09
Skin conductance, spread above baseline	0.70	0.37	0.71	0.38	0.943	0.471	-0.02

Note. Values from the eight-minute simulations are divided by two.

Table 4

Descriptive Statistics of the Intrinsic Motivation Inventory

Construct	Item	*M*	*SD*	Min.	Max.
Interest/enjoyment	1	4.47	1.20	1	6
	5	5.66	1.32	1	7
	7	6.15	0.91	4	7
	9	5.68	1.18	3	7
	14	5.57	1.50	2	7
	16	5.68	1.13	3	7
	20	5.34	1.24	2	7
Perceived competence	4	3.85	1.64	1	7
	11	5.02	1.33	1	7
	12	3.79	1.25	1	7
	15	3.60	1.39	1	7
	22	4.45	1.30	1	7
Perceived choice	3	5.98	1.26	2	7
	10	5.77	1.68	2	7
	18	4.70	1.50	1	7
	19	5.79	1.57	1	7
	21	6.43	1.16	2	7
Pressure/tension	2	5.62	1.93	1	7
	6	5.40	1.74	1	7
	8	5.79	1.23	3	7
	13	6.34	1.26	1	7
	17	6.34	1.11	2	7

Note. Items of the construct pressure/tension are mirrored.

Correlation Analysis

The correlation of participants' intrinsic motivation, their attention, and their SA was investigated by computing a bivariate Spearman's rho correlation coefficient for these variables (see Table 5). Significant correlations are found between the overall intrinsic motivation and all motivational constructs. The correlations between intrinsic motivation and interest/enjoyment, intrinsic motivation and perceived competence, and intrinsic motivation and perceived choice are all positive and large according to Cohen's (1988) interpretations.

The correlation between intrinsic motivation and pressure/tension is negative and large. These results are expected, since the four constructs are used to measure participants' intrinsic motivation, and pressure/tension was theorized by Ryan and Deci (2000) to be a negative predictor of intrinsic motivation. The correlation between interest/enjoyment and perceived competence, and interest/enjoyment and perceived choice are significant, positive, and large as well. Additionally, the correlation between perceived choice and pressure/tension is significant, negative, and medium.

Moreover, the correlation between skin conductance spread above the baseline and heart rate spread above the baseline is significant, negative, and medium. Correlations between skin conductance seconds above the baseline and skin conductance spread above the baseline, and heart rate seconds above the baseline and heart rate spread above the baseline are both significant, positive, and large. Only the correlation between skin conductance seconds above the baseline and heart rate seconds above the baseline is not significant, while both variables are measures for attention.

When investigating the correlations between attention and intrinsic motivation, a significant correlation between skin conductance seconds above the baseline and the construct perceived competence is shown. It is a positive and medium correlation. Skin conductance spread above the baseline correlates significantly with both intrinsic motivation and the construct perceived competence. Both correlations are positive and medium.

Lastly, when studying the correlations between SA and the other variables, no significant correlations were found.

Regression Analysis

To determine a direction on the calculated correlation, bivariate linear regressions were computed between the intrinsic motivation variables and the SA variable, between the attention variables and the SA variable between the attention variables and the SA variable, and between the intrinsic motivation variables and attention variables (see Appendix F). Nevertheless, no significant relationships were found. When analysing the effect of participants' intrinsic motivation on their SA, the variable overall intrinsic motivation accounted for the largest variability in SA. This variability was 5.2%, but no significant effect was found ($F(1, 47) = 2.38$, $p = 0.130$; see Table 6). The effect of participants' attention on their SA was also calculated. The variable skin conductance, spread above baseline reported the largest variability in SA (0.3%). This effect was not significant ($F(1, 47) = 0.11$, $p = 0.744$; see Table 7). When analysing the effect of participants' intrinsic motivation on their attention, the overall intrinsic motivation accounted for the largest variability in skin conductance, seconds above baseline (7.9%), but no significant effect was found ($F(1, 47) = 3.50$, $p = 0.068$; see Table 8).

Multiple linear regression analyses were computed to investigate a relationship between SA and its possible predictors (see Appendix G). However, none of the models accounted for more than 2.9% of the variability in SA. The model with pressure/tension and skin conductance, spread above baseline as predictors for SA accounts for the highest variability, but there is no significant effect found ($F(2, 47) = 0.59$, $p = 0.559$; see Table 9).

Mediation Analysis

Mediation models were computed to analyse if the relationship between intrinsic motivation and SA can be explained by a mediator, attention. In theory, no mediation models could be calculated since no significant correlations were found between any of the variables. Nonetheless, mediation analyses were computed to be able to answer the research question. When analysing the models with intrinsic motivation as a predictor, SA as a outcome variable, and attention as a mediator, none of them shows a significant effect between any of the variables (see Appendix H). For mediation, four conditions must be met: (1) the predictor has to predict the outcome variable significantly; (2) the predictor has to predict the mediator significantly; (3) the mediator has to predict the outcome variable significantly; and (4) the predictor has to predict the outcome variable less strongly when comparing the mediated relationship with the simple relationship (Baron & Kenny, 1986). Since none of the mediation models meet any of the four conditions, this confirms that there is no mediator relationship.

Table 5

Spearman's Correlation Analysis

	Construct	1	2	3	4	5	6	7	8	9	10
1.	Intrinsic motivation	1									
2.	Interest/enjoyment	0.84***	1								
3.	Perceived competence	0.66***	0.52***	1							
4.	Perceived choice	0.71***	0.59***	0.17	1						
5.	Pressure/tension	-0.55***	-0.18	-0.15	-0.33*	1					
6.	Skin conductance, seconds above baseline	0.26	0.27	0.39**	0.07	0.03	1				
7.	Heart rate, seconds above baseline	-0.12	-0.13	-0.20	0.16	-0.01	-0.22	1			
8.	Skin conductance, spread above baseline	0.31*	0.30	0.44**	0.02	-0.05	0.80***	0.33*	1		
9.	Heart rate, spread above baseline	-0.09	-0.10	-0.18	0.17	-0.02	-0.24	1.00***	-0.31*	1	
10.	Situation awareness	0.05	0.08	0.03	0.08	0.04	0.12	0.01	0.11	0.02	1

Note. ***$p < 0.001$ (2-tailed), **$p < 0.01$ (2-tailed), *$p < 0.05$ (2-tailed).

Table 6

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Intrinsic Motivation

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		1.31		2.28	.028
Intrinsic motivation	0.46	0.30	0.23	1.54	.130

Note. Dependent variable: situation awareness.

Table 7

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Skin Conductance, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.35		13.87	<.001
Skin Conductance, spread above baseline	0.14	0.43	0.05	0.33	.744

Note. Dependent variable: situation awareness.

Table 8

Overview Linear Regression Analysis for a Model with Skin Conductance, Seconds above Baseline as Dependent Variable, and as Predictor Intrinsic Motivation

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		122.91		-0.32	.749
Intrinsic motivation	52.10	27.84	0.28	1.87	.068

Note. Dependent variable: skin conductance, seconds above baseline.

Table 9

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Pressure/Tension and Skin Conductance, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.84	0.77		6.26	<.001
Pressure/tension	0.21	0.30	0.11	0.71	.483
Skin conductance, spread above baseline	0.47	0.65	0.12	0.73	.468

Note. Dependent variable: situation awareness.

Table 10

Activity in Simulation during Peaks in Participants' Heart Rate

Category	Behaviour	# detected
Change in simulation	Ending of simulation	4
Mistakes	Driving off asphalt road	3
	Almost driving off asphalt road	1
	Driving against first asphalt compactor	1
	Trying to drive outside of simulation world	1
Exploring	Looking at first asphalt compactor	1
	Looking in left mirror	2
	Looking at dashboard	3
Other	Driving through first turn	1
	Starting engine	6

Analysis of Screen Recordings Based on Psychophysiological Data

To analyse what participants might pay attention to during the asphalt simulation, peaks in the skin conductance and heart rate data were combined with the screen recordings from the experiment. The results showed that the data from participants' skin conductance was unusable. At almost all timestamps of the peaks, the screen recording showed no change in the simulation, and thus the higher skin conductance could not be linked to any change. This might be caused by the higher number of peaks in participants' skin conductance data.

However, peaks from participants' heart rate data were fewer, with 0.74 peaks per participant on average. In total, 35 peaks were found, of which 12 could not be matched with a change in the simulation. At the times of the remaining 23 peaks, the screen recording did show a change, which are: starting the engine, making the first turn, looking at the first asphalt compactor, looking in the left mirror, (almost) driving off the asphalt road, looking at the dashboard, trying to drive outside of the simulation world, and ending of the simulation (see Table 10). For example, one participant was driving forward. At the time of the heart rate peak, they stop and start driving backward off the asphalt. Another driver drives quite rapidly forward. At the time of the heart rate peak, they turn their head towards the left mirror and keep driving forward. Nevertheless, these changes happened during simulations of other participants as well or during the simulation of the same participant at a different timestamp, but without an increase in their heart rate

Discussion and Conclusion

Discussion

This study aimed to investigate a possible relationship between intrinsic motivation and SA, with attention as a possible mediator. To research this relationship, three research questions were answered. First, *Does the intrinsic motivation of vocational education students toward a virtual asphalt training affect their situation awareness during an asphalt training VR simulation?,* second, *Does the attention of vocational education students mediate for the effect of their intrinsic motivation toward a virtual asphalt training on their situation awareness during an asphalt training VR simulation?,* and third, *Can the visual attention of vocational education students be identified from their attention during an asphalt training VR simulation?* Overall, no relationship or effect was found between intrinsic motivation and situation awareness, both with and without attention as a mediator.

The Effect of Intrinsic Motivation on Situation Awareness

For the first research question, it was investigated whether students' intrinsic motivation affected their SA. It was hypothesized that students' intrinsic motivation toward the virtual asphalt training has a positive effect on their SA during the asphalt VR simulation. This hypothesis could not be confirmed in the current study. No significant correlation was found between students' overall intrinsic motivation and their SA. Moreover, the four constructs of intrinsic motivation (interest/enjoyment, perceived competence, perceived choice, and pressure/tension) did not correlate significantly with SA either. Accordingly, when tested for an effect of intrinsic motivation on SA, no significant effect was found, for students' overall intrinsic motivation and the four constructs of intrinsic motivation.

The described findings for this study cannot be compared to previous studies since the relation between intrinsic motivation and SA has not been researched before. However, previous studies have found an effect of attention on SA (e.g., Endsley & Smith, 1996; Gugerty, 1997). Other studies have shown a relationship between one's intrinsic motivation and their attention (e.g., Robinson et al., 2012; Tomporowski & Tinsley, 1996). Thus, a relation between intrinsic motivation and SA could be argued based on previous studies and not finding a relation is therefore unexpected.

A cause of not finding a relation between intrinsic motivation and SA in this study might be a mismatch between one's goal during the simulation and what is asked in the SA questionnaire. Goals are set to achieve one's motivational needs; need for autonomy, need for competence, and need for relatedness (Locke, 2000; Ryan & Deci, 2000). These goals influence what one is aware of in their surroundings since these elements are also integrated into their performance goals (Endsley, 1995a). If the key elements do not correspond with these performance goals, one can decide to look at other elements. However, when the elements in the SA questionnaire do not correspond with all the motivational goals, the results may not reflect the real relation. For example, students might have been motivated and were aware of elements associated with their goal, but answered few questions correctly on the SA questionnaire because the elements in the questionnaire were not related to their goal. Other students might have been motivated and answered more questions correctly on the SA questionnaire because their key elements did correspond with the questions.

Another cause of not finding a relation between intrinsic motivation and SA might be students' different levels of experience with a compactor or VR. When students have more experience, they could have already organized their thoughts and behaviour into a mental model (McVee et al., 2005; Nguyen et al., 2019). Since these models are part of their long-term memory, they can add new information to these stored models (Hoogendoorn et al., 2011; Maes, 1990). In contrast, students with no or less experience do not have these mental models. All information is new and takes up space in the working memory, which leaves less space for SA. Thus, students' prior experiences might intervene with their SA and cause the relationship between intrinsic motivation and SA not to be present.

Attention as Mediator

For the second research question, it was investigated whether students' attention mediated the effect of their intrinsic motivation on their SA. To answer this question, it was hypothesized that students' intrinsic motivation toward the virtual asphalt training has a positive effect on their attention during the asphalt training VR simulation. A Spearman's correlation analysis confirmed a correlation between students' intrinsic motivation and the number of seconds students focus their attention. More specifically, a significant correlation was found between 1) students' overall intrinsic motivation and their skin conductance, spread above baseline, 2) students' perceived competence and their skin conductance, seconds above baseline, and 3) students' perceived competence and their skin conductance, spread above baseline. However, even though a correlation was found between overall intrinsic motivation and skin conductance, spread above baseline, no effect was found when tested for a relationship.

Peculiarly, Potter and Bolls (2012) described heart rate to be a more reliable indicator for one's attention than skin conductance, while this study only shows a correlation between students' skin conductance and intrinsic motivation, and not between their heart rate and intrinsic motivation. Moreover, no correlation was found between students' skin conductance, seconds above baseline and heart rate, seconds above baseline, nor between skin conductance, seconds above baseline and heart rate, spread above baseline, even though all these measures aim to measure attention. This might suggest that the Empatica wristband did not record students' heart rate and/or skin conductance correctly, which is supported by the fact that recordings from the left and right Empatica wristbands differed considerably. This difference in recorded data is unexpected since at least one's heart rate should be the same in both wrists. Nevertheless, users on a forum about the use of the Empatica E4 wristband might have found explanations for the differences in data. De Oliveira Almeida (2019) noted that the heart rate sensor in the Empatica is sensitive to motion. Since participants had to operate the joystick with their right hand and steer the steering wheel with their left hand, they moved both their wrists during the experiment. However, the biggest movements participants made with their right hand, were starting the compactor with a button on the base of the joystick and switching between driving forward and backward. These movements are smaller than moving a steering wheel and therefore data from participants' right hand contains probably less noise than data from their left hand. Ten out of 47 students were lefthanded, so most data used in this study contains less noise. Additionally, Gevonden (2021) noted that the wrist is not the most ideal place to measure one's skin conductance, since it has a limited number of sweat glands. The usable skin conductance data from the Empatica wristband is therefore also limited. Distinguishing which data points for both the heart rate and skin conductance are useable, was not possible. Therefore, these comments might suggest that the Empatica data gathered for this study, contains noise and should be analysed with reservation.

Next, it was expected that students' attention has a positive effect on their SA during the asphalt training VR simulation. This hypothesis was not confirmed by this study. Students' SA did not correlate with any of the indicators of attention and no effect was found between any of the attention indicators and SA. This finding contradicts other studies, which did find a relation between attention and SA. Research showed that people with higher SA, look around more often and scan for possible key elements (Hasanzadeh et al., 2018). They pay closer attention to possible hazards (Endsley & Rodgers, 1998; Gugerty, 1997).

The contradiction of this current study with these previous studies might be caused by the incorrect data points in the Empatica data (De Oliveira Almeida, 2019; Gevonden, 2021). Alternatively, these results might be caused by the questions in the SA questionnaire, which focus on specific elements in participants' surroundings. However, research showed that each individual decides for themselves what elements are important (Yang, 2020). If these elements were not present in the SA questionnaire, it can seem like participants were not aware of their surroundings. While in reality, they might have been aware of key elements in their surroundings, but not the ones the questionnaire asked about.

Lastly, it was hypothesized that students' attention mediates the effect of their intrinsic motivation toward the virtual asphalt training on their SA during the asphalt training VR simulation. This hypothesis was not confirmed by the results of this study. Correlations were not found between intrinsic motivation, attention, and SA. Therefore, no mediation could be calculated. However, to complete this study, the mediation was calculated regardless. The results of this mediation showed that none of the mediator conditions were met. Based on previous studies this finding is unexpected since it was found that attention is a predictor of SA (e.g., Endsley & Smith, 1996; Gugerty, 1997) and that there is a relation between intrinsic motivation and attention (e.g., Robinson et al., 2012; Tomporowski & Tinsley, 1996).

As stated before, not finding a relation between intrinsic motivation and SA with attention as mediation, could be caused by a mismatch between one’s goal during the simulation and what is asked in the SA questionnaire. To accomplish a goal, one must pay attention to the situation around them, which facilitates one’s awareness of elements in their surroundings (Locke, 2000; Endsley, 2000). The SA questionnaire should be applicable to elements of all goals to measure this mediation. However, since no mediator effect was found in this study, questions in the SA questionnaire might not have corresponded with all the goals.

Moreover, not finding a relation can also be caused by students’ different levels of experience with a compactor or VR. Students with more experience might already have a mental model of a similar situation and can add new elements to these models (Hoogendoorn et al., 2011; Nguyen et al., 2019). Students with no experience do not have mental models and have to store all new information in their limited working memory, which leaves less space for SA. Thus, students’ prior experiences might intervene with their SA and cause the relationship between intrinsic motivation and SA not to be present.

Heart Rate as Indicator for Visual Attention

For the third research question, it was explored if visual attention could be identified within the data of the attention indicators. Therefore, the peaks in students’ heart rate were compared with events during the simulation. Some occurred simultaneously. In total, 35 peaks were found, of which 23 took place at the same time as an event in the simulation. During the remaining 22 peaks, no notable events happened in the simulation. These peaks might be caused by events outside of the simulation, such as noise from the school hallway or by unusable data point from the Empatica wristbands (De Oliveira Almeida, 2019; Gevonden, 2021). Nevertheless, the 23 peaks with corresponding events in the simulation might suggest that participants' heart rate did indicate visual attention, at least during these peaks. The participant's visual attention could have been reoriented to a stimulus in the simulation, which caused a peak in their heart rate. However, these events did not only occur during peaks in students' heart rate. The same events happened during simulations of other students as well, where they occurred without an increase in their heart rate. This can again be caused by noise in the heart rate data (De Oliveira Almeida, 2019; Gevonden, 2021). But different people also pay attention to different stimuli. Attention is a variable that can be influenced by multiple variables, such as age and intelligence (Hunt et al., 1989; Fung et al., 2008).

Theoretical and Practical Implications

Although this study shows no expected mediator effect, theoretical implications can be made. This study used screen recordings to identify participants' covert attention and indicate their overt attention. Gaze-tracking can be sufficient in studies like this and instruments to facilitate eye-tracking are not a necessity. Moreover, psychophysiological measures were used to indicate students' attention. By combining gaze-tracking with data from attention indicators, visual attention could be indicated. This might be a more approachable method than measuring visual attention with positron emission tomography (PET) or functional magnetic resonance imaging (fMRI) or indicating visual attention with pupil size (Kanwisher & Wojciulik, 2000; Mathôt et al., 2023).

The results of this study did not support the results of previous studies. However, SA is still an important skill in the engineering field, for task performance and safety reasons (Endsley, 2000). It is therefore essential for teachers to pay attention to this skill. They can make their students aware of SA and practice the skill during classes. Previous research has shown that practicing SA in different situations can help students in future situations since they can rely on their existing mental models (Dattel et al., 2021; Nguyen et al., 2019). During these practices, students can be aware of different elements in their surroundings, based on individual factors including their previous knowledge and goals (Endsley, 1995a).

Limitations

Several limitations should be mentioned when discussing this study because these could affect the generalizability of the results. First, the SA questionnaire might not be the correct instrument to measure students' SA. The questionnaire was filled in by the students after they finished the simulation. A student might be aware of their surroundings during the simulation and not remember the situation after the simulation. Portrat et al. (2008) showed that information from the working memory disappears from the working memory when time passes, and other information enters the working memory. In research, there should be a distinction between SA and memory (Bolls et al., 2001). One's SA could level of SA could be higher during the experiment than when measured afterward.

In addition, items from the SA questionnaire were not divided into the three SA levels; perception, comprehension, and projection (Endsley, 1995a). A factor analysis showed that items from that should be in the same level, did not group together (see Appendix I). Moreover, when items were sorted into the hypothesized levels, the reliability of these levels was low, with a Cronbach's alpha of -0.08 for level 1, -0.21 for level 2, and 0.35 for level 3. Therefore, it was decided to not make the distinction between different SA levels from a methodological perspective. However, because of this decision, a relation between indicators of attention and levels of SA, and intrinsic motivation and its components and levels of SA.

Furthermore, two Empatica wristbands were used for this study. Students wore one around each wrist during the experiment since exploration showed that the wristband can lose contact with the wrist when the arm moves. To moderate the possible lost data, students wore one wristband extra. However, when analysing the gathered data, both wristbands showed incomparable data points. Therefore, data from the wristband of students' dominant hand was used for the analyses, as Empatica (n.d.) suggests. The difference in data might suggest that the data gathered by the wristband is not reliable. Moreover, De Oliveira Almeida (2019) and Gevonden (2021) also noted reasons why data points of both the heart rate and skin conductance data might not be useable. The heart rate sensor in the Empatica wristband was said to be sensible to motions and the wrist is not the best place to measure one's skin conductance.

Moreover, heart rate and skin conductance were used as indicators for attention in this study. Potter and Bolls (2012) state that heart rate is an indicator for cognitive processes, and not only for attention. In turn, skin conductance is an indicator of emotional processes, which influences cognitive processes. Thus, the peaks in heart rate and skin conductance do not have to correspond with attention, but could also be an indicator of, for example, comprehension or memory (Potter & Bolls, 2012). However, when comparing peaks in students' heart rate with the screen recordings, these could be related 23 times. Based on this result, it can be argued that students' heart rate did indicate their attention at least partially.

Finally, to explore students' visual attention, peaks within the heart rate data were linked to the screen recordings of students' simulations. The same comparison was not possible with the skin conductance data and screen recordings. The number of peaks within the skin conductance data were excessive, occasionally one peak every second. This made matching the time of each peak with an event in the simulation at the same time unreasonable. The peaks of students' heart rate were matched with the screen recording, even though students' heart rate did not correlate with their intrinsic motivation and their skin conductance did correlate with their intrinsic motivation.

Future Research

The results of this study initiate future research as well. It is uncertain why there is a difference in the results from previous studies and from this study. Comments by Almeida (2019) and Gevonden (2021) on a forum about the Empatica E4 wristband suggest that part of the heart rate and skin conductance data might contain noise. Therefore, future research should try a different method to indicate participants' attention during another task, for example with a chest band (Ruiz-Malagón et al., 2021). Additionally, the psychophysiological measures could not be distinguished into the constructs of attention; alerting, orienting, and executive attention (Posner & Petersen, 1990). A possible solution could be the thinking-aloud method, where participants are asked to speak their thoughts out loud during a task (Van Someren et al., 1994). This way, researchers are able to collect participants' thought processes without disturbing them. The thinking-aloud method can still be used in combination with gaze- or eye-tracking. By combining both measures, it can also be registered which elements are looked at but are not worthy of thinking about and investigated if these elements can still be used in one's SA.

A possible addition to this future research could be to investigate participants' SA when they do and do not talk about their thoughts during the experiment. Participants might have a higher SA because they process the information deeper when they talk about their thoughts. Another possible outcome might be that participants have a lower SA since talking about their thoughts takes up space in their working memory. That space cannot be used for the levels of SA.

Another solution that influences participants' SA less, would be neuroimaging. This method can measure brain activity with Magnetoencephalography (MEG) and Electroencephalography (EEG; Kanwisher & Wojciulik, 2000; Towey et al., 2019). By analysing these recordings, it can be determined which brain areas were active at a specific time. Researchers can derive when participants were paying attention from this information. Neuroimaging is a more expensive solution than asking participants to speak their thoughts out loud.

Conclusion

This study aimed to investigate a possible (indirect) effect of intrinsic motivation on SA, with attention as a mediator. The results were mostly non-significant with an exception for the correlation between intrinsic motivation and attention. There was neither a correlation between attention and SA nor a correlation between intrinsic motivation and SA. This might be caused by the psychophysiological measures that indicate attention. Therefore, future research should focus on another method to indicate one's attention. It would yield valuable information to investigate participants' attention by asking them to talk about their thoughts during the experiment. Nevertheless, more research is needed on SA to keep the engineering field as effective and safe as possible.

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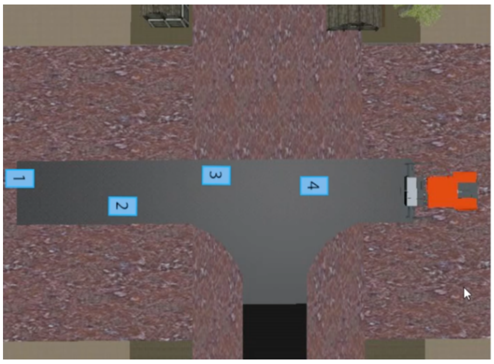
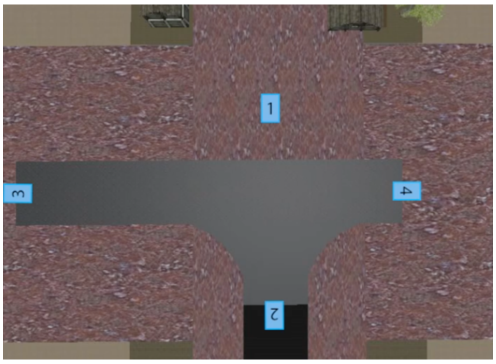
Appendix A. Questionnaire on Situation Awareness

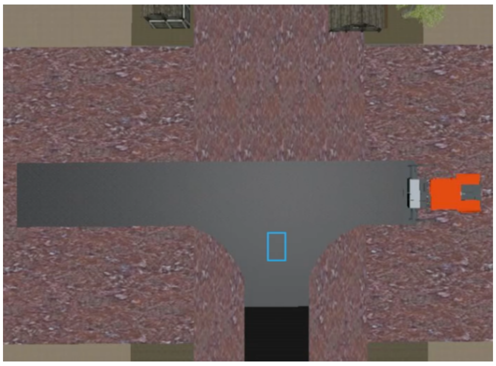
Waar is de eerste wals nu? Klik op de juiste plek op de kaart.
- Plek 1
- Plek 2
- Plek 3
- Plek 4



Waar is de asfaltafwerkmachine nu? Klik op de juiste plek op de kaart.
- Plek 1
- Plek 2
- Plek 3
- Plek 4



Hoe vaak heb je het aangegeven gebied al gewalst?
- Nog niet
- Een of twee keer
- Drie keer of meer



Op welke stand staan je sproeiers nu?
- Uit
- Laag
- Middel
- Hoog

Welke invloed heeft het weer waarbij je aan het werk bent?
- Vanwege het weer hoef ik niet erg dicht bij de asfaltafwerkmachine te blijven.
- Vanwege het weer moet ik zeer grote afstand tot de asfaltafwerkmachine houden.
- Vanwege het weer moet ik iets dichter bij de asfaltafwerkmachine blijven dan wanneer het weer beter is of wanneer het lichter is.

Met hoeveel breedte moet je nu versporen?
- Een halve rolbreedte
- Driekwart rolbreedte
- Dat maakt niet uit

Met welke walsfase ben je nu bezig?
- Voorverdichting
- Elastische fase
- Eindverdichting

Waar moet je het meest op letten gezien de walsfase?
- Of er geen bitumen op het asfalt komen te liggen
- Of het asfalt niet gaat schuiven
- Of de naad wel voldoende is aangewalst

Zal de eerste wals de komende tijd naar een ander gebied verplaatsen?
- Nee
- Ja, ik voorzie veranderingen in het weer
- Ja, ik voorzie tijdelijke veranderingen in de taakverdeling
- Ja, ik voorzie veranderingen in de aanwezigheid van materialen

Voorzie je dat je je walsstrategie moet aanpassen?
- Nee
- Ja, ik voorzie veranderingen in het weer
- Ja, ik voorzie tijdelijke veranderingen in de taakverdeling
- Ja, ik voorzie veranderingen in de aanwezigheid van materialen

Hoe lang duurt het nog tot je brandstoftank leeg is?
- Die is nu leeg
- Die zal snel leeg zijn
- Het duurt nog lang voordat die leeg is

Voorzie je problemen met je taak?
- Ja, ik voorzie problemen met mijn wals
- Ja, ik voorzie problemen met de asfaltkwaliteit
- Ja, ik voorzie problemen met het weer
- Nee

Appendix B. Questionnaire on Intrinsic Motivation

Vragenlijst

* Vragen die je liever niet beantwoordt mag je leeg laten.

Gender:
- ☐ Man
- ☐ Vrouw
- ☐ Anders

Leeftijd: ____ jaar

Naam van je school: ______________________________

In welk jaar van je studie zit je?
- ☐ 1e
- ☐ 2e
- ☐ 3e
- ☐ 4e

Heb je (tijdens stage, school, werk) wel eens een wals bestuurd?
- ☐ Nog nooit
- ☐ Een enkele keer
- ☐ Regelmatig
- ☐ Vaak
- ☐ Heel vaak

Heb je wel eens met een Virtual Reality bril gewerkt?
- ☐ Nog nooit
- ☐ Een enkele keer
- ☐ Regelmatig
- ☐ Vaak
- ☐ Heel vaak

Vragenlijst: Motivatie

Vul voor de 22 stellingen in, in hoeverre ze waar zijn voor jou. Gebruik hiervoor de volgende schaal:

1	2	3	4	5	6	7
Helemaal niet waar			Neutraal			Helemaal waar

		1	2	3	4	5	6	7
1.	Terwijl ik bezig was met de walssimulatie, bedacht ik mij hoe ik ervan genoot	☐	☐	☐	☐	☐	☐	☐
2.	Ik voelde me helemaal niet nerveus over het doen van de walssimulatie	☐	☐	☐	☐	☐	☐	☐
3.	Ik voelde dat het mijn keuze was om de walssimulatie uit te voeren	☐	☐	☐	☐	☐	☐	☐
4.	Ik denk dat ik vrij goed ben in het uitvoeren van de walssimulatie	☐	☐	☐	☐	☐	☐	☐
5.	Ik vond de walssimulatie interessant	☐	☐	☐	☐	☐	☐	☐
6.	Ik voelde me gespannen terwijl ik bezig was met de walssimulatie	☐	☐	☐	☐	☐	☐	☐
7.	Het doen van de walssimulatie was leuk	☐	☐	☐	☐	☐	☐	☐
8.	Ik voelde me ontspannen terwijl ik bezig was met de walssimulatie	☐	☐	☐	☐	☐	☐	☐
9.	Ik heb erg genoten van het doen van de walssimulatie	☐	☐	☐	☐	☐	☐	☐
10.	Ik had niet echt een keuze over het doen van de walssimulatie	☐	☐	☐	☐	☐	☐	☐
11.	Ik ben tevreden met mijn prestatie in de walssimulatie	☐	☐	☐	☐	☐	☐	☐
12.	Ik denk dat ik in vergelijking met andere studenten, vrij goed ben met de walssimulatie	☐	☐	☐	☐	☐	☐	☐
13.	Ik was angstig terwijl ik bezig was met de walssimulatie	☐	☐	☐	☐	☐	☐	☐
14.	Ik vond de walssimulatie saai	☐	☐	☐	☐	☐	☐	☐
15.	Ik voelde me behoorlijk bedreven in de walssimulatie	☐	☐	☐	☐	☐	☐	☐
16.	Ik dacht dat de walssimulatie interessant was	☐	☐	☐	☐	☐	☐	☐
17.	Ik voelde me onder druk gezet terwijl ik de walssimulatie aan het doen was	☐	☐	☐	☐	☐	☐	☐
18.	Ik voelde me alsof ik aan het doen was wat ik wilde doen, terwijl ik bezig was met de walssimulatie	☐	☐	☐	☐	☐	☐	☐
19.	Ik had het gevoel dat ik de walssimulatie moest doen	☐	☐	☐	☐	☐	☐	☐
20.	Ik zou de walssimulatie omschreven als aangenaam	☐	☐	☐	☐	☐	☐	☐
21.	Ik deed de walssimulatie omdat ik geen andere keuze had	☐	☐	☐	☐	☐	☐	☐
22.	Na een tijdje met de walssimulatie gewerkt te hebben, voelde ik me behoorlijk competent	☐	☐	☐	☐	☐	☐	☐

Appendix C. Questions about VR Work Meeting

Correct answer is made bold.

Op welke wals zit jij?
- Eerste
- **Tweede**
- Derde

Hoe ziet het wegprofiel eruit?
- **Dakprofiel in beide richtingen**
- Dakprofiel op de poot
- Dakprofiel op het rechte stuk

Met welke asfaltsoort hebben we te maken?
- DAB
- **SMA**
- ZOAB

Is er iets om rekening mee te houden betreft weer en zicht?
- **Normale temperaturen en zicht**
- Het is erg heet
- Het is donker
- Het regent

Appendix D. Python Code to Extract Participant Data from Empatica Data

```
import datetime
import pandas as pd

date_start = #add start date + time experiment here
date_end = #add end date + time experiment here

##################

file = #file location of Empatica data (EDA)

data = pd.read_csv(file)

basis =int(float(data.columns.values))

date_format_start = datetime.datetime.strptime(date_start,"%m/%d/%Y, %H:%M:%S")
unix_time_start = datetime.datetime.timestamp(date_format_start)

date_format_end = datetime.datetime.strptime(date_end,"%m/%d/%Y, %H:%M:%S")
unix_time_end = datetime.datetime.timestamp(date_format_end)

newdata = data.loc[((unix_time_start - basis)*4 + 1):((unix_time_end - basis)*4 + 1)]
newdata.to_csv(#add file name here)

##################

file = #file location of one participant's data (TEMP)

data = pd.read_csv(file)

basis =int(float(data.columns.values))

date_format_start = datetime.datetime.strptime(date_start,"%m/%d/%Y, %H:%M:%S")
unix_time_start = datetime.datetime.timestamp(date_format_start)

date_format_end = datetime.datetime.strptime(date_end,"%m/%d/%Y, %H:%M:%S")
unix_time_end = datetime.datetime.timestamp(date_format_end)

newdata = data.loc[((unix_time_start - basis)*4 + 1):((unix_time_end - basis)*4 + 1)]
newdata.to_csv(#add file name here)

##################

file = #file location of one participant's data (TEMP)

data = pd.read_csv(file)

basis =int(float(data.columns.values))
```

```
date_format_start = datetime.datetime.strptime(date_start,"%m/%d/%Y, %H:%M:%S")
unix_time_start = datetime.datetime.timestamp(date_format_start)

date_format_end = datetime.datetime.strptime(date_end,"%m/%d/%Y, %H:%M:%S")
unix_time_end = datetime.datetime.timestamp(date_format_end)

newdata = data.loc[((unix_time_start - basis) + 1):((unix_time_end - basis) + 1)]
newdata.to_csv(#add file name here)
```

Appendix E. Python Code to Compute Graphs from Participant Data

```
file = #file location of one participant's data
file2 = #file location of one participant's data during simulation

df = pd.read_csv(file)
df2 = pd.read_csv(file2)

input = list(df.iloc[:, 1])
time = list(df.iloc[:, 0])

start = min(list(df2.iloc[:, 0]))
end = max(list(df2.iloc[:, 0]))

mean = statistics.mean(input)
stdev = statistics.stdev(input)

seconds = 0
for i in range(len(df2)-1):
   if df2.iloc[i][1] >= mean+stdev:
      EDAtime = pd.to_datetime((df2.iloc[i][0]/4+ float(list(df.columns.values)[1])), unit='s')
      HRtime = pd.to_datetime((df2.iloc[i][0]+ float(list(df.columns.values)[1])), unit='s')
      seconds +=1

print(f"seconds above upperbound: {seconds/4}")

plt.plot(time, input, color='red')
plt.title(add graph title here)
plt.xlabel('time')
plt.ylabel('add graph label here')
plt.axhline(y=mean+stdev, color='grey', linestyle='-')
plt.axhline(y=mean, color='blue', linestyle='-')
plt.axvline(x=start, color='black')
plt.axvline(x=end, color='black')
plt.axhline(y=mean-stdev, color='grey', linestyle='-')
#graph for heart rate
plt.ylim(50,130)
#graph for EDA
plt.ylim(0,3)
#graph for temperature
plt.ylim(28,35)
plt.show()
```

Appendix F. Bivariable Linear Regression Analyses

Table 1

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Interest/Enjoyment

Predictor	Unstandardized coefficients		Standardized coefficients		
	B	*SE*	β	*t*	*p*
(Constant)		0.99		3.98	<.001
Interest/enjoyment	0.19	0.18	0.16	1.05	.302

Note. Dependent variable: situation awareness, R^2 = 0.03.

Table 2

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Perceived Competence

Predictor	Unstandardized coefficients		Standardized coefficients		
	B	*SE*	β	*t*	*p*
(Constant)		0.67		6.05	<.001
Perceived competence	0.22	0.16	0.21	1.41	.165

Note. Dependent variable: situation awareness, R^2 = 0.04.

Table 3

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Perceived Choice

Predictor	Unstandardized coefficients		Standardized coefficients		
	B	*SE*	β	*t*	*p*
(Constant)		1.06		3.86	<.001
Perceived choice	0.15	0.18	0.13	10.84	.407

Note. Dependent variable: situation awareness, R^2 = 0.02.

Table 4

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Pressure/Tension

Predictor	Unstandardized coefficients *B*	Unstandardized coefficients *SE*	Standardized coefficients β	*t*	*p*
(Constant)		0.44		11.241	<.001
Pressure/Tension	0.03	0.19	0.03	0.18	.857

Note. Dependent variable: situation awareness, $R^2 < 0.01$.

Table 5

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Heart Rate, Seconds above Baseline

Predictor	Unstandardized coefficients *B*	Unstandardized coefficients *SE*	Standardized coefficients β	*t*	*p*
(Constant)		0.18		26.859	<.001
Heart rate, seconds above baseline	<0.01	0.01	0.01	0.08	.936

Note. Dependent variable: situation awareness, $R^2 < 0.01$.

Table 6

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Skin Conductance, Seconds above Baseline

Predictor	Unstandardized coefficients *B*	Unstandardized coefficients *SE*	Standardized coefficients β	*t*	*p*
(Constant)		0.34		14.44	<.001
Skin conductance, seconds above baseline	<0.01	<0.01	-0.11	-0.07	.946

Note. Dependent variable: situation awareness, $R^2 < 0.01$.

Table 7

Overview Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictor Heart Rate, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.18		26.81	<.001
Heart rate, spread above baseline	-0.06	0.68	-0.01	-0.08	.935

Note. Dependent variable: situation awareness, $R^2 < 0.01$.

Table 8

Overview Linear Regression Analysis for a Model with Heart Rate, Seconds above Baseline as Dependent Variable, and as Predictor Intrinsic Motivation

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		20.01		0.34	.738
Intrinsic motivation	0.39	4.55	0.01	0.09	.933

Note. Dependent variable: heart rate, seconds above baseline, $R^2 < 0.01$.

Table 9

Overview Linear Regression Analysis for a Model with Heart Rate, Seconds above Baseline as Dependent Variable, and as Predictor Interest/Enjoyment

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		15.00		1.22	.229
Interest/enjoyment	-1.78	2.68	-0.10	-0.67	.509

Note. Dependent variable: heart rate, seconds above baseline, $R^2 = 0.01$.

Table 10

Overview Linear Regression Analysis for a Model with Heart Rate, Seconds above Baseline as Dependent Variable, and as Predictor Perceived Competence

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		10.31		0.38	.706
Perceived competence	1.10	2.42	0.07	0.46	.651

Note. Dependent variable: heart rate, seconds above baseline, $R^2 = 0.01$.

Table 11

Overview Linear Regression Analysis for a Model with Heart Rate, Seconds above Baseline as Dependent Variable, and as Predictor Perceived Choice

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		15.91		0.06	.953
Perceived choice	1.31	2.73	0.08	0.48	.635

Note. Dependent variable: heart rate, seconds above baseline, $R^2 = 0.01$.

Table 12

Overview Linear Regression Analysis for a Model with Heart Rate, Seconds above Baseline as Dependent Variable, and as Predictor Pressure/Tension

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		7.01		1.33	.192
Pressure/tension	-0.40	3.11	-0.02	-0.13	.900

Note. Dependent variable: heart rate, seconds above baseline, $R^2 < 0.01$.

Table 13

Overview Linear Regression Analysis for a Model with Skin Conductance, Seconds above Baseline as Dependent Variable, and as Predictor Interest/Enjoyment

Predictor	Unstandardized coefficients		Standardized coefficients		
	B	*SE*	β	*t*	*p*
(Constant)		93.63		0.56	.578
Interest/enjoyment	24.64	16.71	0.22	1.48	.148

Note. Dependent variable: skin conductance, seconds above baseline, R^2 = 0.05.

Table 14

Overview Linear Regression Analysis for a Model with Skin Conductance, Seconds above Baseline as Dependent Variable, and as Predictor Perceived Competence

Predictor	Unstandardized coefficients		Standardized coefficients		
	B	*SE*	β	*t*	*p*
(Constant)		63.37		1.23	.226
Perceived competence	26.78	14.86	0.27	1.80	.079

Note. Dependent variable: skin conductance, seconds above baseline, R^2 = 0.07.

Table 15

Overview Linear Regression Analysis for a Model with Skin Conductance, Seconds above Baseline as Dependent Variable, and as Predictor Perceived Choice

Predictor	Unstandardized coefficients		Standardized coefficients		
	B	*SE*	β	*t*	*p*
(Constant)		101.65		1.75	.087
Perceived choice	1.86	17.45	0.02	0.11	.916

Note. Dependent variable: skin conductance, seconds above baseline, R^2 < 0.01.

Table 16

Overview Linear Regression Analysis for a Model with Skin Conductance, Seconds above Baseline as Dependent Variable, and as Predictor Pressure/Tension

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		44.20		3.42	.001
Pressure/Tension	17.92	19.63	0.14	0.91	.367

Note. Dependent variable: skin conductance, seconds above baseline, $R^2 = 0.02$.

Table 17

Overview Linear Regression Analysis for a Model with Heart Rate, Spread above Baseline as Dependent Variable, and as Predictor Intrinsic Motivation

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.30		0.60	.552
Intrinsic motivation	-0.01	0.07	-0.03	-0.17	.866

Note. Dependent variable: heart rate, spread above baseline, $R^2 < 0.01$.

Table 18

Overview Linear Regression Analysis for a Model with Heart Rate, Spread above Baseline as Dependent Variable, and as Predictor Interest/Enjoyment

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.22		1.51	.139
Interest/enjoyment	-0.04	0.04	-0.15	-0.94	.352

Note. Dependent variable: heart rate, spread above baseline, $R^2 = 0.02$.

Table 19

Overview Linear Regression Analysis for a Model with Heart Rate, Spread above Baseline as Dependent Variable, and as Predictor Perceived Competence

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.16		0.59	.560
Perceived competence	0.01	0.04	0.04	0.26	.798

Note. Dependent variable: heart rate, spread above baseline, $R^2 < 0.01$.

Table 20

Overview Linear Regression Analysis for a Model with Heart Rate, Spread above Baseline as Dependent Variable, and as Predictor Perceived Choice

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.24		0.16	.872
Perceived choice	0.02	0.04	0.06	0.39	.702

Note. Dependent variable: heart rate, spread above baseline, $R^2 < 0.01$.

Table 21

Overview Linear Regression Analysis for a Model with Heart Rate, Spread above Baseline as Dependent Variable, and as Predictor Pressure/Tension

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.11		1.38	.175
Pressure/tension	-0.01	0.05	-0.02	-0.16	.877

Note. Dependent variable: heart rate, spread above baseline, $R^2 < 0.01$.

Table 22

Overview Linear Regression Analysis for a Model with Skin Conductance, Spread above Baseline as Dependent Variable, and as Predictor Intrinsic Motivation

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.46		-0.14	.886
Intrinsic motivation	0.18	0.10	0.26	1.72	.094

Note. Dependent variable: skin conductance, spread above baseline, R^2 = 0.07.

Table 23

Overview Linear Regression Analysis for a Model with Skin Conductance, Spread above Baseline as Dependent Variable, and as Predictor Interest/Enjoyment

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.34		0.62	.542
Interest/enjoyment	0.09	0.06	0.22	1.46	.151

Note. Dependent variable: skin conductance, spread above baseline, R^2 = 0.05.

Table 24

Overview Linear Regression Analysis for a Model with Skin Conductance, Spread above Baseline as Dependent Variable, and as Predictor Perceived Competence

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.23		1.36	.182
Perceived competence	0.10	0.06	0.26	1.72	.092

Note. Dependent variable: skin conductance, spread above baseline, R^2 = 0.07.

Table 25

Overview Linear Regression Analysis for a Model with Skin Conductance, Spread above Baseline as Dependent Variable, and as Predictor Perceived Choice

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.37		1.91	.063
Perceived choice	<-0.01	0.06	<-0.01	-0.01	.991

Note. Dependent variable: skin conductance, spread above baseline, $R^2 < 0.01$.

Table 26

Overview Linear Regression Analysis for a Model with Skin Conductance, Spread above Baseline as Dependent Variable, and as Predictor Pressure/Tension

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)		0.16		3.63	<0.001
Pressure/tension	0.06	0.07	0.12	0.76	.449

Note. Dependent variable: skin conductance, spread above baseline, $R^2 = 0.01$.

Appendix G. Multiple Linear Regression Analyses

Table 1

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Intrinsic Motivation and Skin Conductance, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.88	1.97		2.47	.018
Intrinsic motivation	0.10	0.37	0.05	0.28	.779
Skin conductance, seconds above baseline	<0.01	<0.01	0.07	0.43	.670

Note. Dependent variable: situation awareness, $R^2 = 0.01$

Table 2

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Intrinsic Motivation and Heart Rate, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.90	1.97		2.49	.017
Intrinsic motivation	0.12	0.37	0.05	0.34	.738
Heart rate, seconds above baseline	0.01	0.02	0.09	0.58	.567

Note. Dependent variable: situation awareness, $R^2 = 0.01$

Table 3

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness Mean as Dependent Variable, and as Predictors Intrinsic Motivation and Skin Conductance, Spread above Baseline

Predictor	Unstandardized coefficients *B*	Unstandardized coefficients *SE*	Standardized coefficients β	*t*	*p*
(Constant)	4.80	1.97		2.45	.019
Intrinsic motivation	0.09	0.37	0.04	0.24	.814
Skin conductance, spread above baseline	0.51	0.65	0.12	0.78	.441

Note. Dependent variable: situation awareness, $R^2 = 0.02$

Table 4

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Intrinsic Motivation and Heart Rate, Spread above Baseline

Predictor	Unstandardized coefficients *B*	Unstandardized coefficients *SE*	Standardized coefficients β	*t*	*p*
(Constant)	4.88	1.97		2.48	.018
Intrinsic motivation	0.13	1.37	0.06	0.35	.726
Heart rate, spread above baseline	0.43	1.01	0.07	0.43	.673

Note. Dependent variable: situation awareness, $R^2 = 0.01$

Table 5

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Interest/Enjoyment and Skin Conductance, Seconds above Baseline

Predictor	Unstandardized coefficients *B*	Unstandardized coefficients *SE*	Standardized coefficients β	*t*	*p*
(Constant)	4.69	1.47		3.20	.003
Interest/enjoyment	0.14	0.27	0.09	0.53	.601
Skin conductance, seconds above baseline	<0.01	<0.01	0.06	0.35	.731

Note. Dependent variable: situation awareness, $R^2 = 0.01$

Table 6

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Interest/Enjoyment and Heart Rate, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.55	1.48		3.07	.004
Interest/enjoyment	0.18	0.26	0.11	0.69	.496
Heart rate, seconds above baseline	0.01	0.02	0.10	0.66	.516

Note. Dependent variable: situation awareness, R^2 = 0.02

Table 7

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Interest/Enjoyment and Skin Conductance, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.63	1.46		3.17	.003
Interest/enjoyment	0.12	0.27	0.07	0.45	.653
Skin conductance, spread above baseline	0.46	0.66	0.11	0.70	.488

Note. Dependent variable: situation awareness, R^2 = 0.02

Table 8

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Interest/Enjoyment and Heart Rate, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.55	1.450		3.04	.004
Interest/enjoyment	0.18	0.26	0.11	0.69	.493
Heart rate, spread above baseline	0.53	1.02	0.08	0.52	.605

Note. Dependent variable: situation awareness, R^2 = 0.02

Table 9

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Interest/Enjoyment and Heart Rate, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	5.06	1.02		4.95	<.001
Perceived competence	0.10	0.24	0.07	0.40	.690
Skin conductance, seconds above baseline	<0.01	<0.01	0.06	0.35	.729

Note. Dependent variable: situation awareness, R^2 = 0.01

Table 10

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Perceived Competence and Heart Rate, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	5.09	1.00		5.08	<.001
Perceived competence	0.11	0.24	0.08	0.48	.636
Heart rate, seconds above baseline	0.01	0.02	0.09	0.55	.585

Note. Dependent variable: situation awareness, R^2 = 0.01

Table 11

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Perceived Competence and Skin Conductance, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.98	1.02		4.88	<.001
Perceived competence	0.08	0.24	0.05	0.32	.754
Skin conductance, spread above baseline	0.47	0.67	0.12	0.71	.482

Note. Dependent variable: situation awareness, R^2 = 0.02

Table 12

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Perceived Competence and Heart Rate, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	5.09	1.01		5.05	<.001
Perceived competence	0.12	0.24	0.08	0.50	.620
Heart rate, spread above baseline	0.41	1.01	0.06	0.40	.689

Note. Dependent variable: situation awareness, $R^2 = 0.01$

Table 13

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Perceived Choice and Skin Conductance, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.67	1.60		2.91	.006
Perceived choice	0.13	0.27	0.08	0.49	.625
Skin conductance, seconds above baseline	<0.01	<0.01	0.07	0.47	.642

Note. Dependent variable: situation awareness, $R^2 = 0.01$

Table 14

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Perceived Choice and Heart Rate, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.86	1.55		3.14	.003
Perceived choice	0.12	0.27	0.07	0.46	.649
Heart rate, seconds above baseline	0.01	0.02	0.09	0.55	.585

Note. Dependent variable: situation awareness, $R^2 = 0.01$

Table 15

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Perceived Choice and Skin Conductance, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.48	1.61		2.79	.008
Perceived choice	0.13	0.26	0.08	0.51	.616
Skin conductance, spread above baseline	0.53	0.64	0.13	0.82	.415

Note. Dependent variable: situation awareness, $R^2 = 0.02$

Table 16

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Perceived Choice and Heart Rate, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.85	1.55		3.13	.003
Perceived choice	0.13	0.27	0.08	0.48	.637
Heart rate, spread above baseline	0.40	1.01	0.06	0.39	.696

Note. Dependent variable: situation awareness, $R^2 = 0.01$

Table 17

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Pressure/Tension and Skin Conductance, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.99	0.77		6.50	<.001
Pressure/tension	0.22	0.30	0.12	0.74	.465
Skin conductance, seconds above baseline	<0.01	<0.01	0.06	0.37	.714

Note. Dependent variable: situation awareness, $R^2 = 0.02$

Table 18

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Pressure/Tension and Heart Rate, Seconds above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	5.04	0.69		7.31	<.001
Pressure/tension	0.24	0.30	0.13	0.81	.422
Heart rate, seconds above baseline	0.01	0.02	0.09	0.61	.549

Note. Dependent variable: situation awareness, R^2 = 0.03

Table 19

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Pressure/Tension and Skin Conductance, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	4.84	0.77		6.26	<.001
Pressure/tension	0.21	0.30	0.11	0.71	.483
Skin conductance, spread above baseline	0.47	0.65	0.12	0.73	.468

Note. Dependent variable: situation awareness, R^2 = 0.03

Table 20

Overview Multiple Linear Regression Analysis for a Model with Situation Awareness as Dependent Variable, and as Predictors Pressure/Tension and Heart Rate, Spread above Baseline

	Unstandardized coefficients		Standardized coefficients		
Predictor	*B*	*SE*	β	*t*	*p*
(Constant)	5.06	0.69		7.31	<.001
Pressure/tension	0.24	0.30	0.13	0.81	.424
Heart rate, spread above baseline	0.44	1.00	0.07	0.44	.660

Note. Dependent variable: situation awareness, R^2 = 0.02

Appendix H. Mediation Analyses

Figure 1

The Role of Skin Conductance, Seconds above Baseline as a Mediator for Intrinsic Motivation in Predicting Situation Awareness

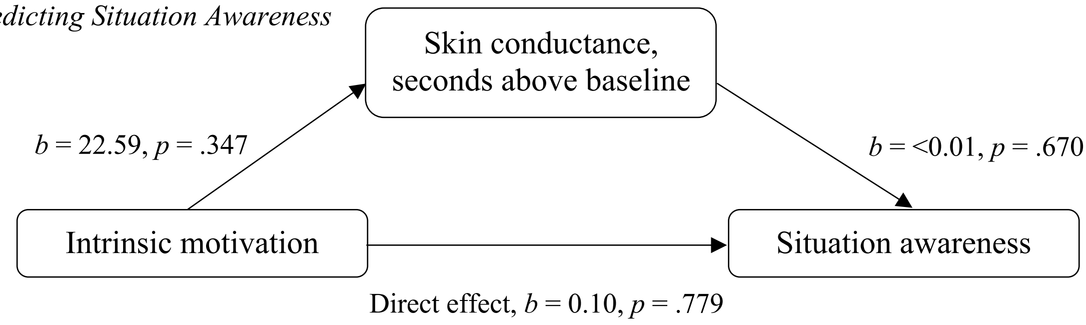


Figure 2

The Role of Heart Rate, Seconds above Baseline as a Mediator for Intrinsic Motivation in Predicting Situation Awareness

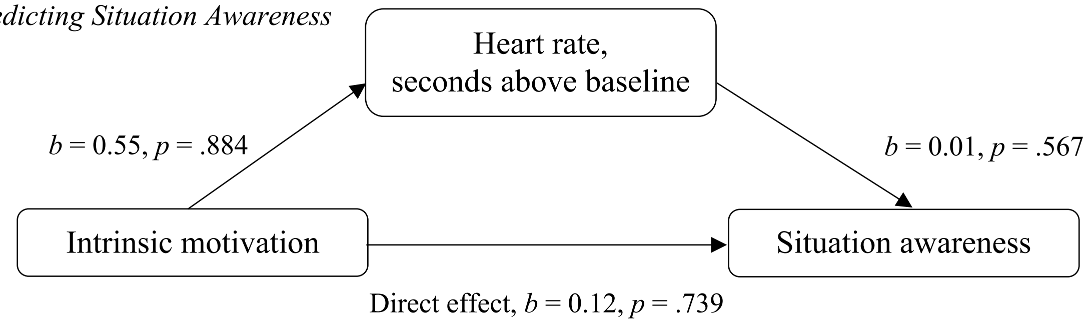


Figure 3

The Role of Skin Conductance, Spread above Baseline as a Mediator for Intrinsic Motivation in Predicting Situation Awareness

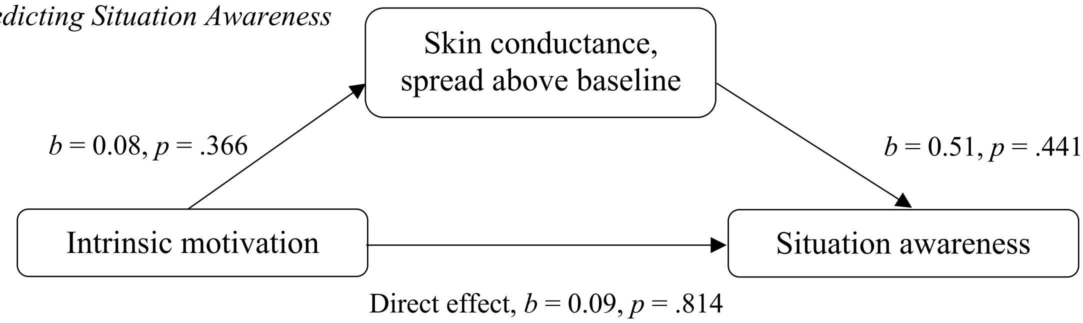


Figure 4

The Role of Heart Rate, Spread above Baseline as a Mediator for Intrinsic Motivation in Predicting Situation Awareness

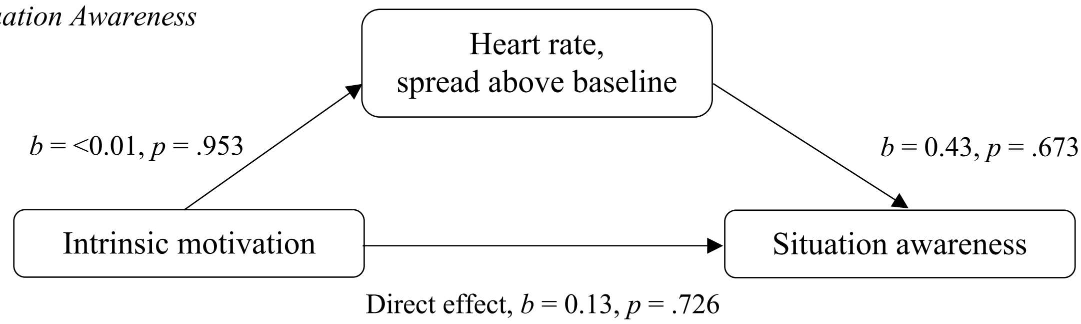


Figure 5

The Role of Skin Conductance, Seconds above Baseline as a Mediator for Interest/Enjoyment in Predicting Situation Awareness

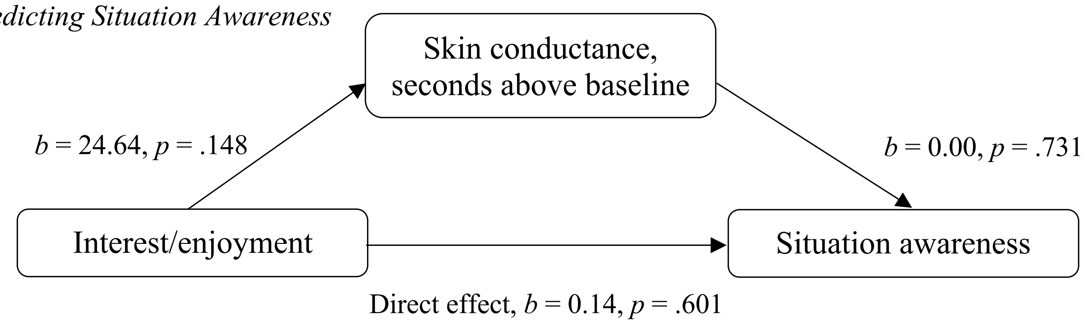


Figure 6

The Role of Heart Rate, Seconds above Baseline as a Mediator for Interest/Enjoyment in Predicting Situation Awareness

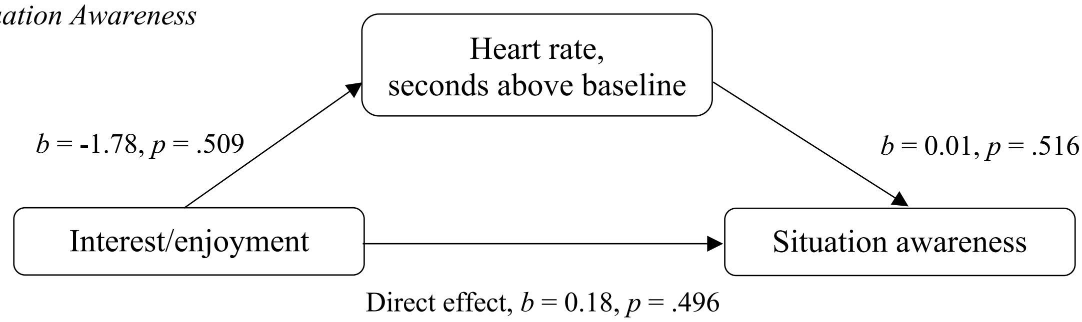


Figure 7

The Role of Skin Conductance, Spread above Baseline as a Mediator for Interest/Enjoyment in Predicting Situation Awareness

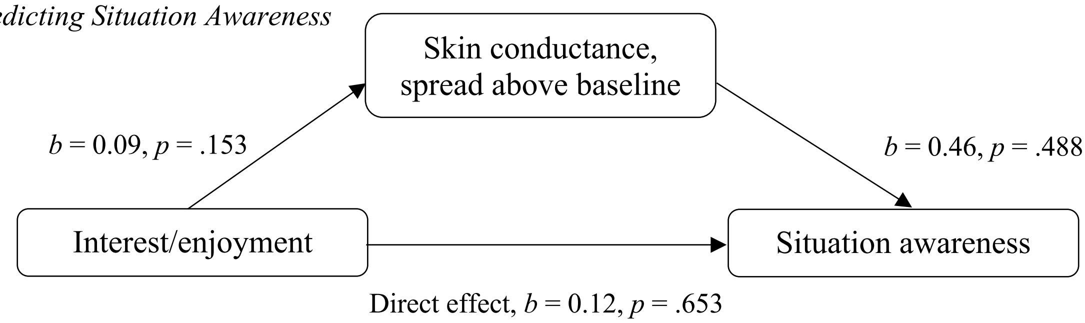


Figure 8

The Role of Heart Rate, Spread above Baseline as a Mediator for Interest/Enjoyment in Predicting Situation Awareness

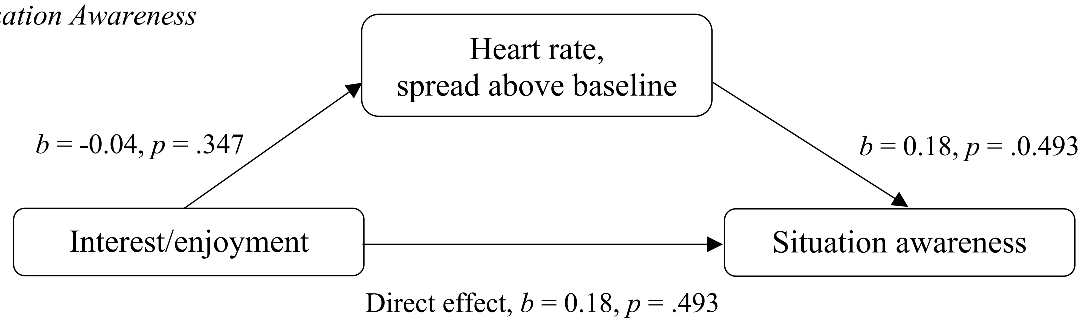


Figure 9

The Role of Skin Conductance, Seconds above Baseline as a Mediator for Perceived Competence in Predicting Situation Awareness

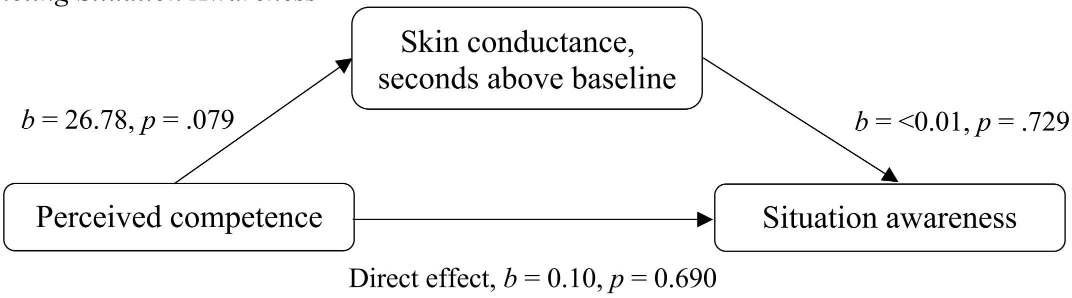


Figure 10

The Role of Heart Rate, Seconds above Baseline as a Mediator for Perceived Competence in Predicting Situation Awareness

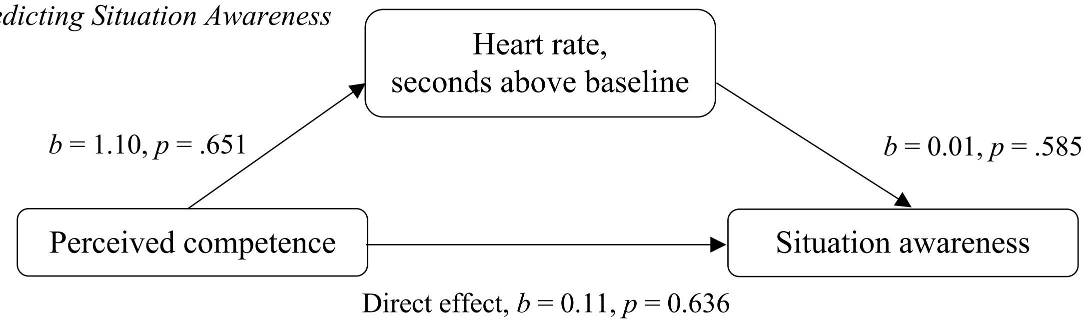


Figure 11

The Role of Skin Conductance, Spread above Baseline as a Mediator for Perceived Competence in Predicting Situation Awareness

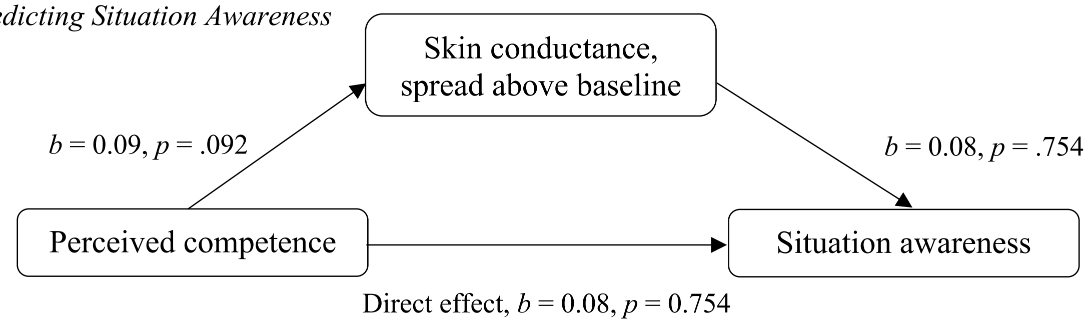


Figure 12

The Role of Heart Rate, Spread above Baseline as a Mediator for Perceived Competence in Predicting Situation Awareness

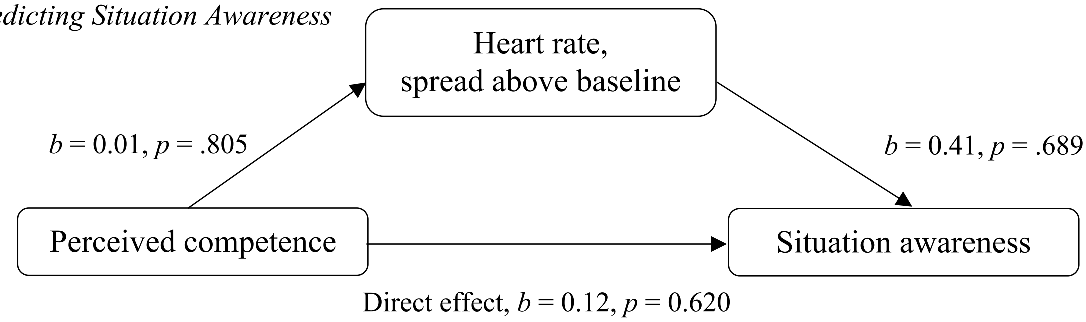


Figure 13

The Role of Skin Conductance, Seconds above Baseline as a Mediator for Perceived Choice in Predicting Situation Awareness

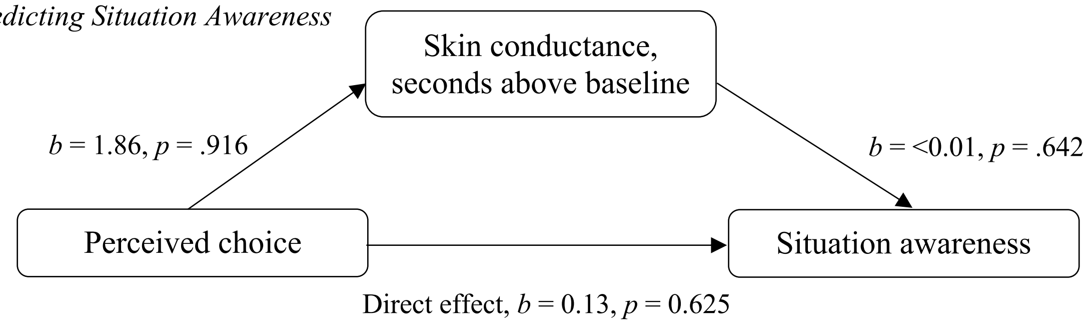


Figure 14

The Role of Heart Rate, Seconds above Baseline as a Mediator for Perceived Choice in Predicting Situation Awareness

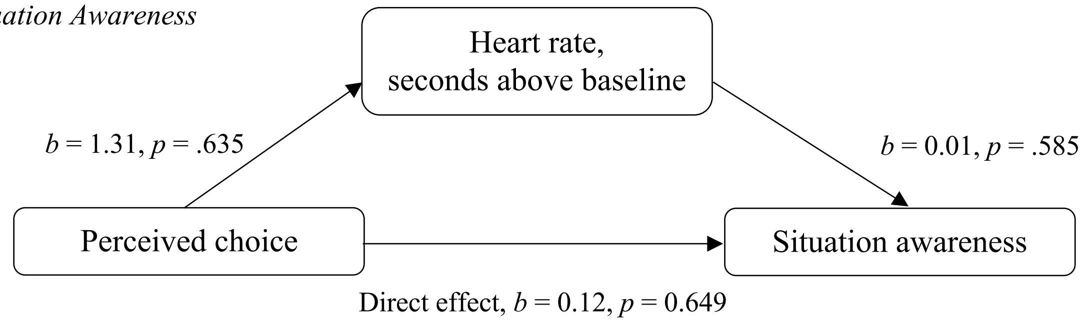


Figure 15

The Role of Skin Conductance, Spread above Baseline as a Mediator for Perceived Choice in Predicting Situation Awareness

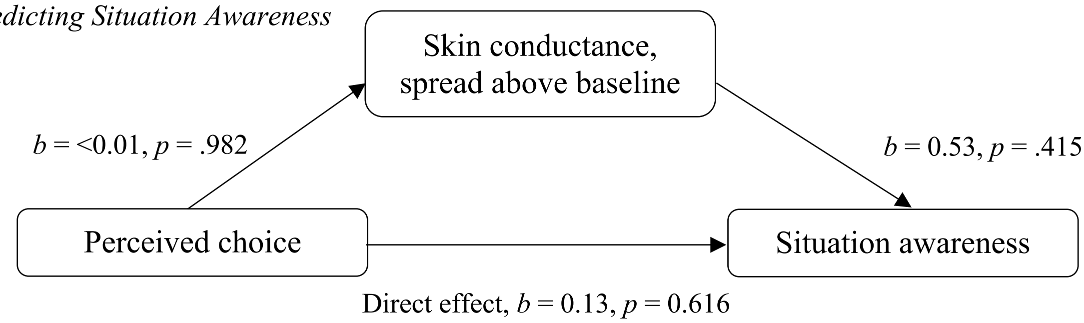


Figure 16

The Role of Heart Rate, Spread above Baseline as a Mediator for Perceived Choice in Predicting Situation Awareness

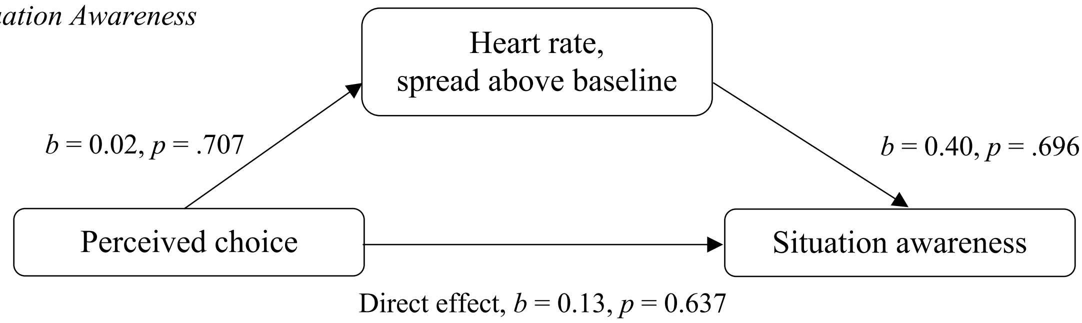


Figure 17
The Role of Skin Conductance, Seconds above Baseline as a Mediator for Pressure/Tension in Predicting Situation Awareness

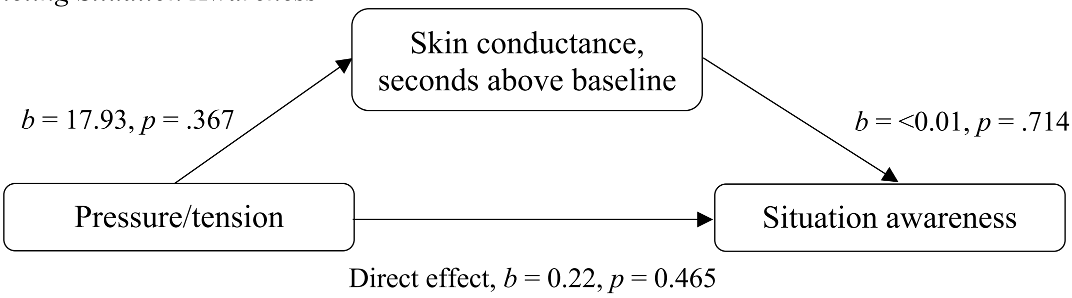


Figure 18
The Role of Heart Rate, Seconds above Baseline as a Mediator for Pressure/Tension in Predicting Situation Awareness

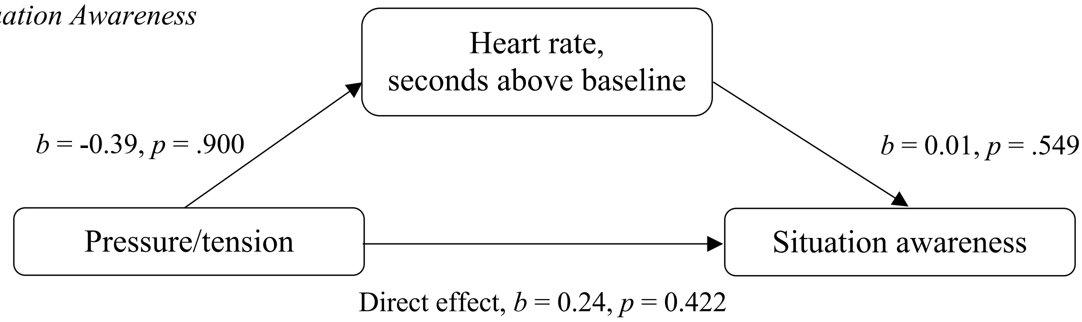


Figure 19
The Role of Skin Conductance, Spread above Baseline as a Mediator for Pressure/Tension in Predicting Situation Awareness

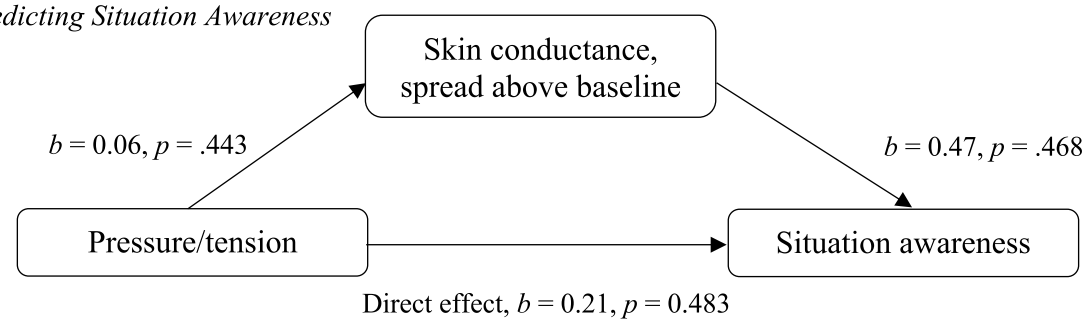
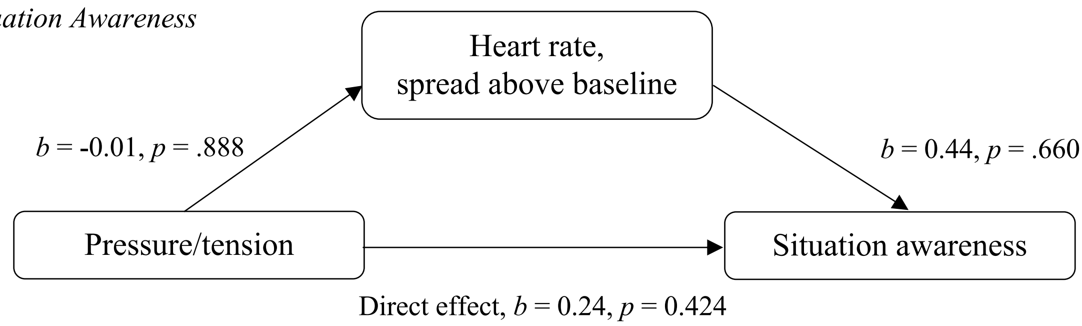


Figure 20
The Role of Heart Rate, Spread above Baseline as a Mediator for Pressure/Tension in Predicting Situation Awareness



Appendix I. Factor Analysis of Situation Awareness Questionnaire

Table 1

Factor Analysis of the Situation Awareness Questionnaire

Items		Factor loading		
		1	2	3
Level 1 of SA				
1	Where is the first asphalt compactor now?	-0.253	0.299	**0.486**
2	Where is the asphalt paver now?	0.383	**0.470**	-0.113
4	Which setting are your sprinklers in now?	0.196	-0.187	**0.538**
Level 2 of SA				
5	What effect does the weather have on your work?	0.270	0.493	**0.530**
6	With how much width do you have to track now?	0.419	**-0.691**	-0.090
Level 3 of SA				
9	Will the first asphalt compactor transfer to another area?	**0.760**	0.237	-0.021
10	Do you need to adjust your strategy in the future?	**0.788**	-0.264	0.084
11	How long will it take for your fuel tank to be empty?	0.227	**0.526**	-0.485
12	Do you foresee problems with your task?	0.033	-0.071	**0.468**

Note. Extraction method: Principal Component Analysis.